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MINING COAL BY THE STRIPPING METHOD

By S. A. Taylor*

We shall consider this subject in the order in which we would analyze it if we were going into it as a commercial proposition.

The first thing is, of course, to secure the property. To secure a good stripping property is more of an engineering problem than is ordinarily attributed to the undertaking.

The initial step is to make a reconnaissance survey to determine if there is sufficient acreage of coal of sufficient thickness and of a light enough overburden to warrant going into the proposition further. This survey is generally made by using the barometer and lock level, locating the 50-foot contour line above the outcrop of the coal. From this information an estimate of the acreage of coal is made, to determine if there is a sufficient tonnage of coal to warrant the construction of a plant.

Next, the character of the overburden is ascertained as far as possible; for, if this should be solid rock, as it is over some seams of coal, it generally cannot be stripped at a cost that would make the proposition commercially successful.

The next step is to ascertain the availability of railroad connections and the location and probable cost of railroad sidings and tipples.

An examination is also made of the water-supply, to determine if there can be water enough secured for the shovels and engines needed in the operation, and likewise the availability of electric power for an electric outfit, should that be the kind of power desired.

This preliminary survey frequently proves the property undesirable, and as a general thing many of the properties fail on this preliminary examination, but if it shows possibilities of being a good property the next step is to survey, map, and drill it.

If there is any question as to markets for the coal, this feature of the proposition should be gone into carefully, while doing the mapping and drilling.

*Consulting Engineer, Pittsburgh.

The next step after finding a property which warrants the engineering work is to have a topographical survey made of the land showing all of the facts that can be ascertained, such as roads, buildings, oil wells and any coal openings and outcrops of the coal. After this has been made, the property should be drilled to determine the character and thickness of the overburden, and also the thickness and character of the coal. This drilling should be done systematically, at uniform distances. It is also well to dig a few wells down through the overburden and coal as a check on the drilling and to enable a more thorough study of the overburden and coal.

After the drilling of the property there should be made a topographical map of the coal, showing just how it dips and where the low points in the coal vein occur. With this information at hand the engineer is now prepared to lay off the method of operation, and here is where the real value of engineering shows to advantage in determining the location of permanent drains so as to reduce the pumping of pits, if the field is capable of self-drainage. If not, then where all water collecting in the pits can be brought by gravity to the low point and the permanent pumping plant installed there.

These things all determined, the next matter is to determine the best location of the railroad connections and tipple. In the determination of tipples, if there is a chance for selection from several sites, the main question will be the selection of the best site and one that will require the shortest haul for the coal from the property, taken as a whole. Very frequently, however, this does not become a question, as the location of the serving railroad prohibits any selection of sites; but where there is a chance to select the location it should be done from an engineering standpoint, keeping in mind the economy of operation.

The tipple should be constructed with picking tables, screens, loading booms and the necessary machinery to clean and prepare the coal for market.

I think it only fair to state here that this is a feature which has been overlooked by many stripping operators to the detriment not only of the particular plant but to the industry in general, for without the careful preparation of the coal a stripping operation

which otherwise has fairly good conditions will likely prove a failure. This has been the history of many operations which have proved disastrous.

The machinery now used in stripping operations is the outgrowth of evolution of machines of different types and combinations.

In anthracite stripping, use is made of a strong heavy contractor's shovel, which loads the overburden into dump cars —something similar to a railroad contractor's outfit. Large installations are equipped somewhat like the Panama Canal. This method is not commercially successful in bituminous coal stripping operations on account of the cost.

The early scheme of operation was with small shovels, handling the dirt either in dump cars or by conveyor system. There have been a few of the conveyor system outfits which have been successful, but generally the overburden consists of various kinds of material which does not handle well on one type of conveyor, as a conveyor designed to handle one kind of material will not handle other classes of material equally well.

As a result of experimenting, the present method of operation is to have a large revolving shovel operated either by steam or electric power, with a boom of 80 to 90-foot centers, a dipper stick of from 50 to 55 feet, and a bucket of from five to eight cubic yards capacity, depending on the character of the material to be handled.

This shovel would have an operating radius of approximately 150 feet and a practical dumping height of 65 feet above the level of the top of coal.

The initial cut is made by the shovel cutting itself down onto the top of the coal and making a cut from 75 to 100 feet in width, depending upon the depth of overburden. The material thus excavated is deposited at one side if there is sufficient room; if not, then on both sides. The length of this cut is determined by the extent of the property.

The small shovel, called the loading shovel, is a shovel mounted on caterpillar tractors and equipped with a boom of 30 to 35 feet and a dipper stick of 25 to 30 feet, with a bucket or dipper

of from 1.5 to 2.5 cubic yards capacity, which loads out approximately a width of 30 feet of coal and loads this coal either directly into railroad cars or into self-dumping cars to be conveyed to the tipple.

This loading shovel follows up the stripping shovel the entire length of the cut and loads out the coal behind the stripping shovel, leaving a berm of coal 45 feet wide for the stripping shovel to operate upon on the return cut.

The stripping shovel then starts back and takes a cut 30 feet wide, depositing the material thus excavated into the cut where the coal was loaded out, and continues this process unless otherwise interfered with, until the field is exhausted.

The amount of overburden that can be excavated is determined by the spoil banks; or in other words, the amount of depth of overburden that can be handled is dependent upon the amount of space to deposit the material. However, with overburden consisting of clay and shales, the maximum amount is generally not over 45 feet of overburden and not over 6 to 1, that is, 6 feet of overburden to each foot of coal, but here again caution must be used and engineering calculations brought into play to determine what amount of overburden can be moved per ton of coal produced. This is done by determining the cost of producing coal as compared with what it can be sold for, which after all is the deciding factor for successfully handling the proposition commercially.

In connection with the stripping of the overburden, if this is hard shale or some rock, a great saving can be effected by drilling and shooting the overburden, as it not only increases the amount of material that can be removed in a given time, but at the same time saves the wear and tear of the shovel and also saves power. We have found in practice that a good way to do this shooting is to lay the holes off 20 to 25 feet apart in the form of a hexagon, and shoot well back into the solid. This enables the action of the elements to assist in disintegrating the materials. and makes the handling much more economical (See Fig. 1).

The drilling is done by an ordinary well drill operated by steam, gasoline, or electricity. In like manner, if the coal is very hard, it becomes well worth while to shoot the coal, as this pro-

duces coal of much larger lumps, saves the wear and tear on the shovels, and also saves power.

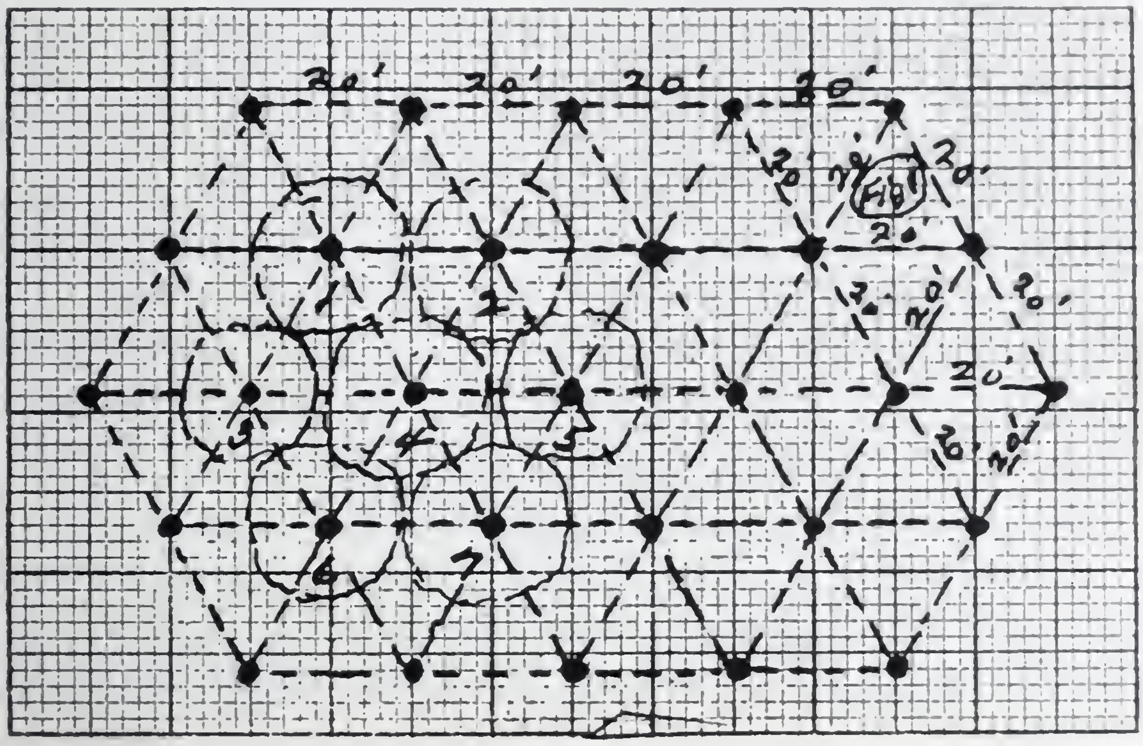

Fig. 1. Arrangement of Drill Holes for Blasting Overburden.

We have found the jack-hammer type of pneumatic drill the best adapted to this work, as it cleans out the hole as it is being drilled and is quite rapid in operation.

There has been a great deal of consideration given to the question of which kind of equipment is the best to use—that is, whether to use electric shovels or steam-shovels, and this is a question which probably cannot be decided in the abstract.

If the location of your plant is close to a power line, and in a climate where very cold winters occur or where no water fit for boiler purposes can be secured at reasonable rates, the decision will probably be to use electric machines, but over against these factors must be the consideration that electric shovels cost considerably more for the first installation than do steam-shovels. Again, they are a more delicate machine, they require close attention, and the cost of upkeep is generally greater. In the operation of electric machines, there is also some danger from electric shock, due to the leakage of current by reason of the insulation on cables getting worn through and the moisture from rain and snow completing the circuit with the ground through the man handling the equipment.

On the other hand, in the operation of steam plants the water question is one requiring considerable attention; first of all, to secure an adequate quantity of water of the quality necessary to operate boiler plants without a heavy cost for water treatment or upkeep of the boilers.

Another problem is the matter of the water lines freezing in cold weather and throwing the shovels out of commission, for while the main water lines may be buried deep enough under the surface to prevent freezing yet the small service lines leading from main lines out to the shovels, on account of moving from place to place, cannot be entirely covered and as a result they give considerable trouble during cold weather.

The item favoring steam equipment is the lower first cost; also in the operation of the steam shovels it is not so hard to secure men who understand steam power to operate the shovels, and steam machinery is more rugged, and therefore more nearly fool-proof.

The question of keeping the water out of the pits is of great importance and requires careful consideration, not only to preserve good working conditions but to give the loading shovel a dry, solid foundation from which to load the coal. Where water is permitted to remain in the pit, there is great danger of getting some of the fire-clay under the coal loaded at the same time and mixed with it, and, also, the coal being wet allows some of this clay to adhere to the coal and thus makes it harder to clean. Again, the water gives trouble in cold weather through the freezing of slack and dirt to the coal and clogging up the machinery at the dump and tipple.

It will be apparent to all that one of the big questions in a stripping plant is the matter of transportation of the coal from the pit to the tipple. This is a phase of the operation which cannot be very well treated in a general way, for at each plant a very detailed study should be made of the best method of solving the problem, keeping in mind always an equipment to balance the keeping of the tipple and shovels in constant operation. This will require ample passing sidings to be constructed, having in view a trip of cars always at the shovel to be loaded, and one trip always at the dump house, and as many trips on the track in be-

tween as will keep the shovel steadily working. In other words, the work should be laid out and planned so as to provide a well balanced operation, all of which requires some careful efficiency studies by a competent engineer.

DISCUSSION

Mr. H. L. Beach:* Is it customary to start the shovel into the coal at the high or low point of the coal seam? It would seem to me that, if you start at the top, the water will have to seep down through the coal or be pumped out; whereas, if you start at the low point, the water will run away from the shovel giving a dry bed on which to operate.

Mr. S. A. Taylor: That is the idea, to do that as well as we can. Wherever you can do it you should follow the low lines and have the water flow away from the shovel. If you have a local swamp in the coal you have to use pumps. We have a portable pump run by an electric motor for this purpose and in this case we throw the water out over the spoil banks and allow it to seep away.

Mr. W. A. Weldin:† Do you prefer a side dump-car? There is an advantage in using standard contractors' dump-cars, in that they are readily obtainable, but it seems to me they have such a high center of gravity and so much mechanism that it would pay to buy the running gear and build a simple box thereon; even though this would necessitate a special dump—perhaps a revolving dump. The high center of gravity is hard on tracks and the general up-keep of cars and tracks must be high.

Mr. S. A. Taylor: Yes, in most cases. In the conditions we have here the side-dump cars are the kind to use. We use an ordinary five-yard, side-dump, contractors' car. That is a very easy car to operate. As they come in they just knock the chains loose and these automatic pushers dump the cars, and we right them with the pulling lever. We get good service out of them. Just now we are experimenting with a new 10-yard car in which the sockets or resting points in the center of the car are lower and the dumping angle reduced to 30 degrees. The ordinary car is made to dump at an angle of 45 degrees; but that is not necessary

*Vice-President and Sales Engineer, Clarke Car Co., Pittsburgh.
†Blum, Weldin & Co., Pittsburgh.

with coal and the extra angle and the speed of dumping tend to break up the coal more. We are not sure that this will work out but we think it will.

Mr. W. M. Parkin:* Referring to the method of shooting the overburden, do you drill those holes through to the coal or do you drill on down through the coal?

Mr. S. A. Taylor: We attempt to keep about a foot or a foot and a half above the coal.

Mr. W. M. Parkin: Do you desire to shatter the coal?

Mr. S. A. Taylor: No. In this case we have a rock over the coal and we stop two feet above that. We put a stick or a stick and a half of dynamite in after the hole is drilled to force out anything that is in the hole, and then we use a different kind of explosive after that. By doing this it shatters the rock down to the coal but does not disturb the coal.

Mr. W. A. Weldin: About how far apart are those holes?

Mr. S. A. Taylor: From 20 to 25 feet. After we get the first open cut made we can determine exactly what kind of material we have to strip and then we can tell how far apart to put the holes. That rock does not cover the entire field, so in some places we put the holes as far apart as 30 feet, and from that down to 18 feet. Our first practice was to drill two rows of holes parallel with the cut. We found that that would shoot large chunks of rock out on to the coal and we had to break them up. But by keeping the holes well back from the front we get better results and in rainy weather the water will seep down and in freezing it will disintegrate the rock, and we find it well worth while.

As to giving an approximate cost, that is pretty hard to do. It always depends on conditions. We had costs as high as 39 cents a ton of product, in one month; but in that month we did a great deal of shooting and did not get so much coal out. To get

*Engineer, W. M. Parkin & Co., Pittsburgh.

that exact it should be carried over a period until you exhaust all the coal that is shot. Our cost of shooting would probably average 20 to 25 cents a ton; but it is well worth while because you save your machinery and the cost of power as well. In the operation of the shovels a great deal of power can be saved just in the handling of the machinery. An inexperienced operator will insist on every shovel being run up to the maximum height. The best thing to do is to build up from the bottom gradually. By installing that practice we cut our power bills down as much as 30 per cent.

Mr. W. M. Parkin: Is a central power-plant desirable as a source of supply?

Mr. S. A. Taylor: We do use a good deal of current. Our current costs us pretty close to 10 cents a ton. Take the condition that exists out west, in Wyoming for instance, where they have very cold winters and there is no central power-plant near from which to buy power. I have worked over that a little and I am still inclined to believe that it would be cheaper to build a power-plant equivalent to two shovels. You would have to bury the water lines eight or nine feet to keep them from freezing (I have known them to freeze at 10 feet) and you could not keep your feed lines to the steam-shovels covered up. You have to keep a portion of these lines open to the air going to the shovel and when the weather gets below zero you will have the pipes freezing. So that with conditions such as those with a two-shovel plant I think a central power-plant would be desirable.

Mr. W. M. Parkin: Do you adopt any method of cleaning dirt from your slack?

Mr. S. A. Taylor: In the slack from the No. 8 district you have very little dirt. Out in Ohio in No. 6 there are two layers of slate—one about half way down and another near the bottom—and that is very brittle. It is almost an impossibility to keep that slack good. It ought to be jigged, but in that country there is no water. The result is that the slack is a by-product and they have to sell it for just what they can get.

Mr. W. B. Spellmire:* You speak of using a jack-hammer drill. Do you use a core-drill occasionally to observe changes under the surface?

Mr. S. A. Taylor: After we have started the shovel we never drill. I do not mean that we use the jack-hammer drill for drilling the overburden. We have some steam drills and several driven by gasoline engines but most of them are driven by electric motor—just the ordinary well drill.

Mr. Phelan McShane:† What, in your experience, would be considered the life of a Marion No. 300 shovel, with reasonable maintenance?

Mr. S. A. Taylor: We set up a sinking-fund charge of 25 cents a ton when we started eight years ago, but we have had several years when that did not take care of the repairs and upkeep. I believe the shovel companies claim the shovel is virtually worn out in ordinary digging such as clay and shale in producing 1,000,000 tons of coal; but, when you have rock and hard digging, a production of 500,000 tons of coal would be the life of the shovel. So if you are going to count depreciation of the shovel you ought to count it on the basis of not exceeding 500,000 tons of coal produced. As to the exact life, it is pretty hard to say anything. I have seen some shovels that have been running five or six years and are just about as good as new; in other words, the repairs have kept them up. We have had that experience and I know others who have had the same experience.

The shovel represents a process of development. The big shovels they have now have given trouble in a good many places. On the electric shovel, just where the motor is located a lot of the cross beams have given way, and on three shovels we have had to reinforce those beams. On some shovels that are coming out next year those beams will be twice as heavy as on the present shovels.

*Local Manager, General Electric Co., Pittsburgh.

†General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Mr. H. L. Beach: In the metal-mining field, the shovel is something like the small boy's pocket knife: He wears out the blade and gets a new one, then he wears out the handle and replaces it; still he has the same knife. With this degree of up-keep, a shovel is almost new after ten years service and, while out of date mechanically, still works as well as it ever did. Why, therefore, buy a new shovel?

Regarding the proposition just mentioned, of a power-station for generating electric power where the load consists principally of two or three electrically driven shovels, the load factor on the station would be very low thus making the plant operation most uneconomical. When a shovel is making a cut, it draws heavily on the source of supply and, when swinging and dumping, the demand is almost nothing. If you could so connect the shovels that the two would alternate in their cutting operations it would simplify matters, but the first thing you know, both are cutting at one time and your power-plant must have sufficient capacity for the load.

Where they buy power from large central-power companies in the West, their power bills are based on a peak-load demand. To keep this as low as possible, motor-generator sets are installed with huge fly-wheels and rheostatic control of the motor automatically regulated to allow the entire set to slow down under heavy load, thus absorbing the stored up energy in the fly-wheel. When the load decreases, the set speeds up again to normal. This stabilizes the demand on the central power-station and brings their load factor to a maximum.

Mr. S. A. Taylor: I did not mean to advocate that at all, but the difficulty you have with your water-pipes freezing would possibly justify putting in an electric station.

You would have to have a power-station with a capacity sufficient to handle the peak-load of both shovels simultaneously. This same plant could probably handle four shovels as easily as two, since two would probably be the maximum that would happen to pull at the same time.

In the western part of Ohio the equipment is practically all electric and in a good portion of Indiana it is electric.

Wherever they can get good water I think they generally use steam-shovels, but in some portions of the country you can not get good water.

Mr. W. B. Spellmire: Is the maintenance of electric shovels higher than that of steam-shovels?

Mr. S. A. Taylor: Yes.

Mr. W. B. Spellmire: How do you account for that?

Mr. S. A. Taylor: The supply materials are higher in cost and there are a good many more delicate parts in the electric shovel than in the steam-shovel.

Mr. W. B. Spellmire: I am informed that the maintenance per locomotive mile on the New York Central system was five cents per mile after the electrification as compared with 20 cents per mile with steam locomotives.

Mr. S. A. Taylor: But you have a much higher type of engineer operating on the railroad than on a shovel. Most of the men who run shovels are accustomed to steam-shovels, while the electric shovel has come in only within the last few years and as a result we do not get as good men.

Mr. W. B. Spellmire: Then the trouble is due to inexperience of the men and not the fault of the electric shovel.

Mr. S. A. Taylor: Not entirely. Our supplies for electric shovels are away in excess of those for the steam-shovel in cost; but the new type of electric shovel will be very much better than the old one.

With electrical machinery you always have the problem of insulation. This inherently is made from non-metallic materials and naturally will not stand the constant jar and jolt of a shovel as well as the rugged parts of a steam-engine. The up-keep on the new electric shovel should be cut very materially. You have individual drive motors for each particular part of the work. I

should think that would cut down the up-keep of the electric shovel over the present shovel 20 to 25 per cent.

During the war the electric shovel cost about $135,000. The small No. 36 cost up to about $35,000. The model 300 steam-shovel got up to as high as $110,000. To-day you can buy the present form of steam-shovel for $80,000 to $85,000 and the smaller one for about $24,000.

Mr. H. E. Cole:* Reference was made to the difficulty in keeping water-supply lines open in very cold weather in steam-operated plants. That is a difficult proposition since nearly all water-supply lines must be moved freqently in order to supply the stripping and loading shovels and hence cannot very well be covered. We have largely overcome this difficulty by putting about eight coils into the feed-water line, forming a kind of basket in which a coal fire is kept burning. This raises the temperature of the water sufficiently so that it can be safely carried quite a distance without other protection; provided, of course, that there is a slight movement through the pipe at all times. Where the line is exceptionally long, more than one set of coils may be necessary.

Mr. S. A. Taylor: As far as I know we have never had any trouble with our feed lines. The main feed lines are buried about three feet deep. What we have our trouble with is the small pipes that come out from the main feed lines to the edge of the bank where they connect on the hose. We have had trouble there a number of times. Your scheme might help that some but I am not sure. You would heat the water to some extent, to keep it from freezing?

Mr. H. E. Cole: That is the idea exactly. This method worked out very successfully in an operation with which I am connected where formerly we had experienced a great deal of delay from freezing.

Did you ever experiment with large standard-gage dump-cars? In the limestone quarries in Michigan they use a large dump-car in connection with all sizes of shovels.

*Vice-President and General Manager, Harris Pump & Supply Co., Pittsburgh.

MR. S. A. TAYLOR: No, we always used narrow gage. The cars hold about five tons.

MR. W. A. WELDIN: What would you think of the idea of using a plain car and revolving dump? Of course you can make the revolving dump long enough to dump several cars at once.

MR. S. A. TAYLOR: We can dump three or five of these cars while we are dumping one on a revolving dump.

I might say that we keep an efficiency table on our shovels, figuring it out every month, and the efficiency is very low. If you get 40 to 45 per cent. of the capacity of the shovel you are doing pretty well, and if you get a man who can make 50 to 55 per cent. he is a good operator. The main factor is in the runner and not in the shovel itself. We record the time closed down when necessary to make repairs, and the time not necessary, and from that we figure out the actual running time each one has worked during the month and make the allowance for necessary and unnecessary stoppage. Regarding the two kinds of shovels, I do not now recall that there is any material difference.

MR. W. A. WELDIN: I think this discussion is growing interesting. Mr. Paul, can you add something?

MR. J. W. PAUL:* I had several questions in mind but most of them have been asked and answered; consequently I have nothing further to say.

MR. W. B. SPELLMIRE: The advocates of the electric shovel claim that, when it is properly designed and constructed, the absence of delays due to repairs makes it possible for the electric shovel to produce an output of 20 per cent. in excess of the steam-shovel. To-day we do not consider the use of steam for an ore bridge, coal bridge or Hewlett unloader, and it should not be necessary to consider steam for the shovel. Possibly many shovels were originally designed for steam, and, as an afterthought, electrical equipment was installed. Obviously, the resulting electric shovel was not properly designed as such.

*Mining Engineer, Pittsburgh Experiment Station, U. S. Bureau of Mines.

Mr. S. A. Taylor: I can not answer that. I can see the logic of it but I do not know whether that will be the case or not. I know there is no material difference in operation between the old style electric shovel and the steam shovel.

Mr. G. G. Bell:* I listened to Mr. Taylor's paper with great interest. While I have had no experience with the stripping process of mining coal, I have operated a plant in which probably 100,000 to 200,000 tons of stripped coal were burned in a year. This coal was overlaid with a heavy sandstone cover, and was expensive to strip, so eventually the thin cover was mined by the stripping process and the thick cover by ordinary mining methods. This was Pittsburgh coal, the upper section of which contains considerable slate, fusing at a low temperature.

The power-plant operators preferred the mined coal to the stripped coal. This I think was undoubtedly due to neglect to strip off and discard the proper amount of coal from the top of the seam, or to pay sufficient attention to the drainage, which undoubtedly resulted in considerable clay being loaded with the coal. The coal was very soft and, though it was picked, the slack was not removed from it when it was being picked. If this field had been thoroughly explored before the work was started, and the low point of the coal determined and proper facilities made for drainage, undoubtedly the coal shipped out would have been of a superior quality. I believe that conditions are such that there is greater possibility of getting dirt mixed with the coal when it is mined by the stripping process; and that a thoroughly efficient and well trained organization is required.

Mr. Taylor mentioned the fact that an electrically operated shovel had a higher maintenance cost than one operated by steam, and was noisier. This is undoubtedly due to the design of the shovels. The general experience with motors for driving power-plant auxiliaries is that they cost less to maintain than steam-engine drive or steam-turbine drive for auxiliaries. Of course, conditions with shovels are different; but a properly designed motor—eliminating clutches and gears for reversing, which introduce considerable additional mechanism—and the use of an

*Manager Power Department, West Penn Power Co., Pittsburgh.

individual motor of reversing type for each operation, will undoubtedly make a considerable reduction in the maintenance, and the amount of noise made by the shovel.

MR. W. A. WELDIN: It might be of interest if Mr. Taylor can tell us why in several of his tipples, preference is given to picking *before* the shaker screen, rather than *after* it. Why not pick on a combined picking table and loading boom after the shakers have made the separation, and thus save a unit?

MR. S. A. TAYLOR: Where the coal contains much dirt of a friable nature, it is better, as far as possible, to get all the dirt picked out before it becomes more broken up by passing over the shaking screens. Again, it is more difficult to take care of dirt picked out on loading booms on account of the space being small between the cars into which the loading booms are delivering the coal. We do, however, pick on the loading booms any dirt we miss on the picking tables.

MR. H. A. DEUEL:* Would it not be advisable to put in jigs to reduce the ash in the slack?

MR. S. A. TAYLOR: Water is too scarce.

MR. H. A. DEUEL: I wish to call attention to an installation of air concentrating tables that have been installed in the coal washer at the Colorado Fuel & Iron Company's plant at Pueblo, Colo. They were using the wet process and had four 4-compartment jigs. These were later replaced by 18 air tables, breaking all the coal used by the coke plant consisting of 120 Koppers ovens. The coal is of a uniform fineness, being crushed in a Bradford breaker. The results have been most satisfactory, reducing the ash in the final coke and showing a saving at the blast-furnaces in pounds of coke per ton of pig-iron.

MR. S. A. TAYLOR: Do you know anything about the cost of that process?

*Chief Expediter, The Koppers Company, Pittsburgh.

Mr. H. A. Deuel: I think it costs less money. They just made that change last year, and I am not familiar with all the details. It is for coke, which is rather fine—finer than ordinary slack and more uniform.

Mr. S. A. Taylor: In reply to Mr. Bell's statement that conditions are such in stripping that there is greater possibility of getting dirt in the coal, and that a thoroughly efficient and well trained organization is required to keep the coal clean, I should like to add something which was probably not brought out very clearly in the paper.

Our practice is to have a gang of three or four men with picks and shovels go over the coal immediately in advance of the loading shovel and clean all the slate and dirt off as completely as they can. After this is done we use brooms made of steel wire and sweep off the fine dirt as completely as possible. When this is done there is very little dirt left to get into the coal.

THE MODERN INDUSTRIAL GEAR.

By W. H. Phillips* and L. F. Burnham†

INTRODUCTION

The definition of a gear may be a device for transmitting power continuously at a uniform rate. A gear should be rated on its ability to satisfy the following requirements:

Reliability, length of life, effect on adjacent equipment, efficiency, first and consequential costs, quietness.

Power must be transmitted continuously with a degree of reliability that insures the uninterrupted operation of the particular equipment. The performance of the gear is just as important to that particular equipment and its functioning is just as necessary to that machine as the operation of a department is to the plant as a whole. After this reliability has been established, the less important though no less tangible efficiencies may be investigated.

The seriousness of vibration, whether of great or small amplitude, has always been recognized; and to no small degree, vibration may be traced to the gear. The bearings that wear out too quickly, the shafts and pedestals that get out of alignment, the machine parts that become fatigued and fail, the motors that wear out commutators and brushes too quickly, and the armature leads that break—all these may be traced, in part at least, to vibration. Any formula figuring depreciation of equipment must be multiplied by a constant representing vibration.

Increasing the life of a hard-worked gear means far more than the saving in initial investments, which may be trivial. Tripling the life of the gear cuts the cost of the gear to one-third, but it also does away with removing two worn-out gears and installing two new gears. It eliminates the necessity of having the particular equipment shut down, possibly for hours, with its possible effect upon still other equipment dependent upon the first. These shut-downs often entail enormous loss of production. These far

*Manager, Engineering Department, R. D. Nuttall Co., Pittsburgh.
†Mechanical Engineer, R. D. Nuttall Co., Pittsburgh.

reaching delays are serious and, in the interests of lower costs, must be avoided.

The permissible reduction in sizes due to improved material, heat treatment and greater tooth strength through design offers new possibilities in effecting substantial savings in material and space. This, together with higher efficiency through better tooth forms and greater accuracy in manufacture, affects power consumption and, while this effect may be small, it is continuous.

Some of the street railways are going over the design of their cars, looking for excess weight, estimating that this weight costs them 10 cents per pound per year to carry around.

One of the surest indexes to the efficiency of a gear is the noise it makes. Aside from the losses that are resulting from this noisy gear, it does not tend to promote efficient man power especially when confined in a relatively small space or building. Such a gear should be investigated.

DESIGN

In considering this subject, a brief sketch of the evolution of gearing should be included. There is little that is strictly new to-day in gear mathematics. The writers are in possession of portions of Willis' "Principles of Mechanism" 1841; also edition of 1870.* Willis mentions practically all the properties of gearing as now understood, with references to early writers, as far back as 1615. It is fair to say the history of modern gearing starts contemporaneously with the mechanical revolution of the last two centuries or earlier. However, accurate gearing had to await the development of the modern machine-tool, for gearing is no better than the means to produce it.

Most early gears were cast, instead of machined, using the cycloidal tooth form. Cast gears still survive for rough service in mills, etc., but are found less and less frequently, as the modern, heat-treated, cut gear gives superior action and life. Very recently, with the development of die casting, a die-cast gear for small powers has been brought out but has not received wide approval as it is made of non-ferrous alloys. To-day for

*Principles of Mechanism, by Robert Willis. Ed. 2, 1870. Longmans, London.

uniform power transmission, the cut steel involute gear is predominant.

There are many curves which could be used for gear-tooth contours, but of these the involute is the most valuable. It permits alteration of center distance without effect on uniform velocity ratio, it is easily cut by the generating process and its mathematical properties are susceptible of exact study for the purpose of designing gearing according to any desired specifications. The cycloidal system is lacking to some extent in the properties mentioned, and is seldom, if ever, found except in a cast or rotary cut gear.

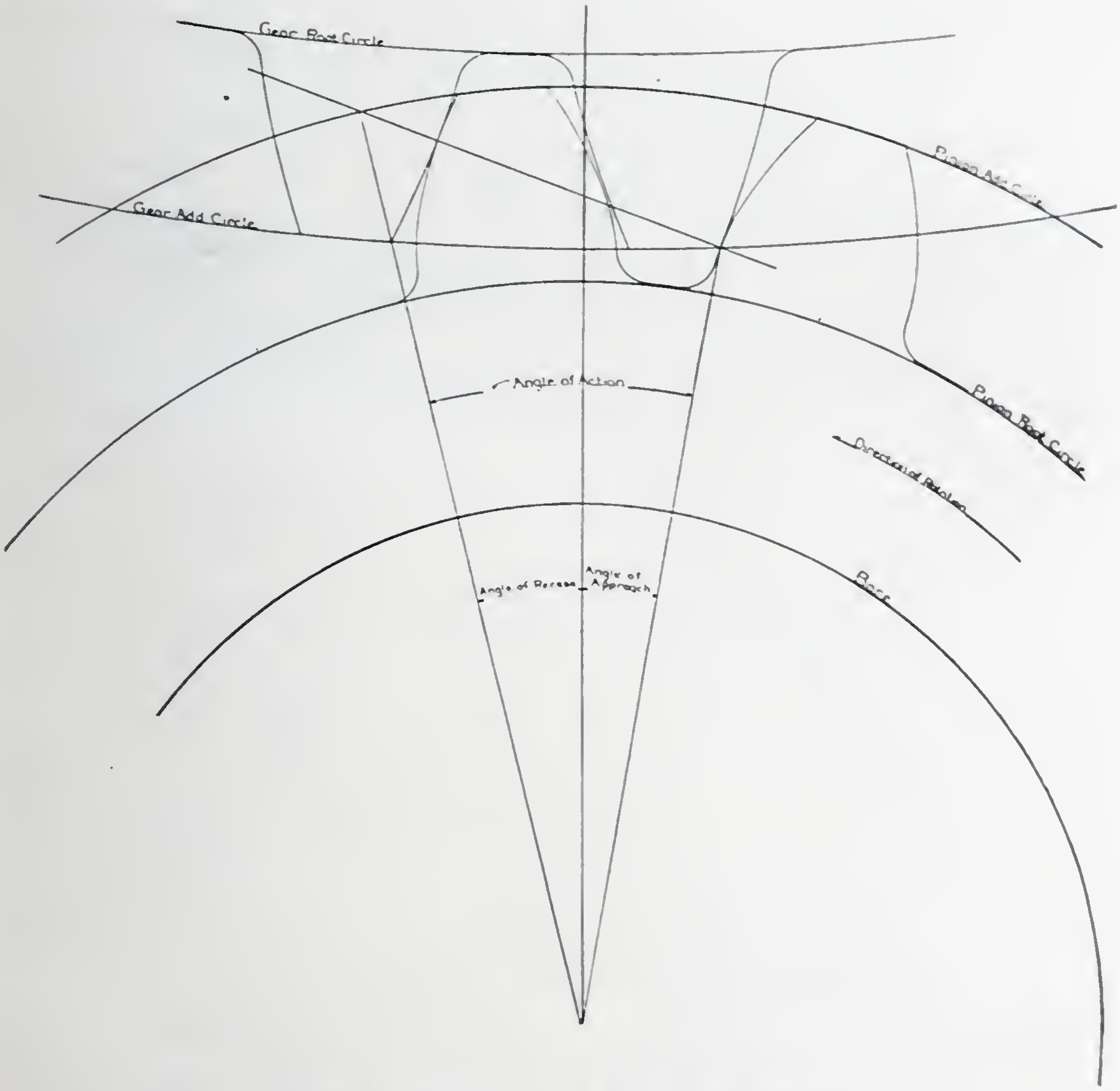

Fig. 1. Angle of Action of Gear.

The general mathematics of involutes will not be discussed in this paper. There is a wealth of literature on the subject for those interested. It is essential, however, to know that the

straight-sided teeth of a rack are involutes and that one involute will generate another. The hobbing and shaping process of generating involute gears are based on this fact.

The long and short addendum gear set has a long addendum on the driver and a short addendum on the driven. Experience shows that such a set runs more quietly than a set with equal addenda. This, apparently, is due to the friction of approach being greater than the friction of recess, hence the desirability of lengthening the addendum of the driver, thus shortening the angle of approach. See Fig. 1-2 for angles of action.

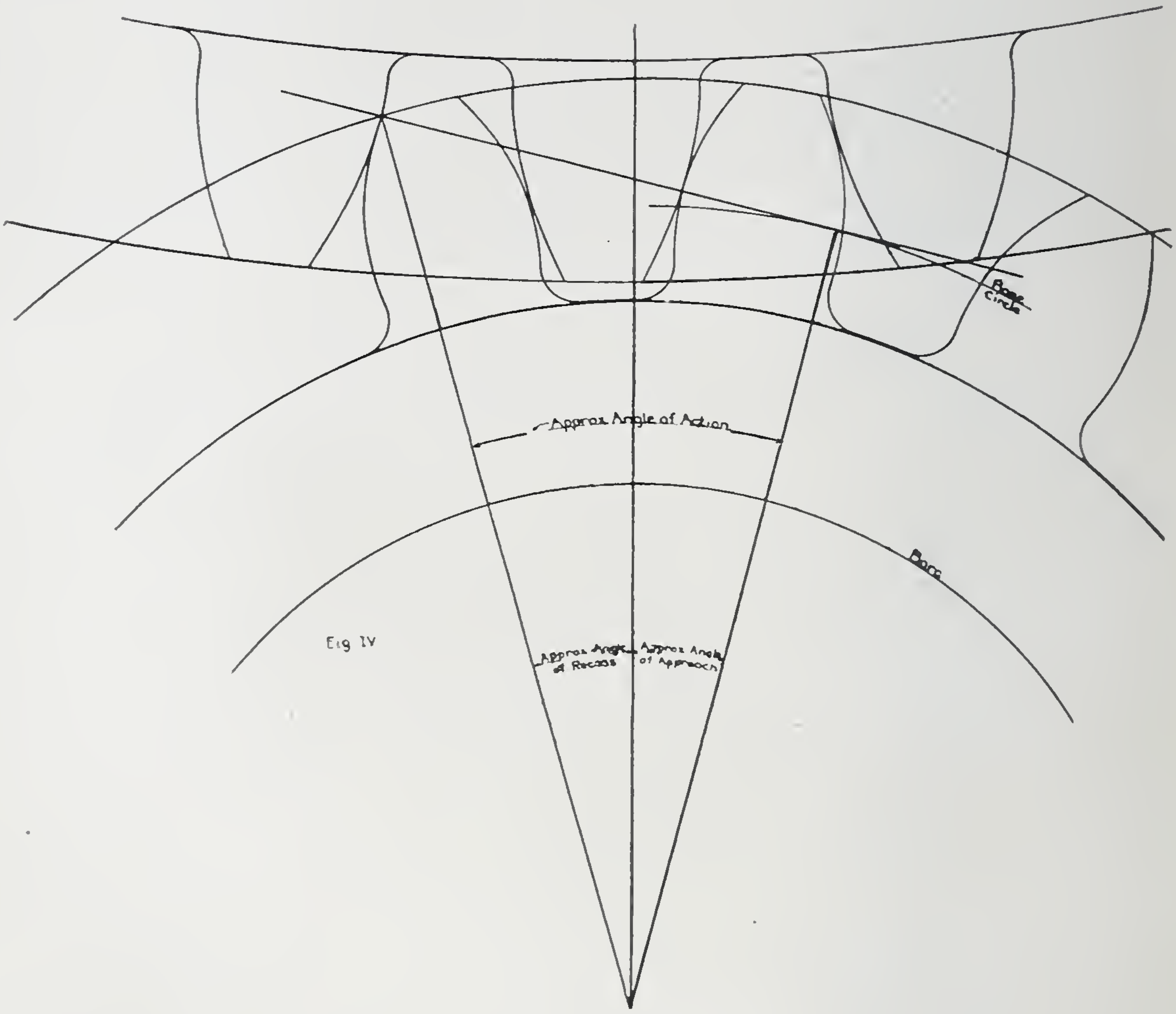

Fig. 2. Angle of Action of Gear.

Stubbing or shortening gear teeth, greatly increases the strength of gearing, due to a decrease in leverage from tip to root. Fig. 3 shows the stub tooth superimposed on the standard.

Pressure angles have been used from the original 14½ degrees of the Brown & Sharpe system, up to 22½ degrees in some

mill practice. Increasing the pressure angle increases strength, due to utilizing a more favorable portion of the involute, giving a narrower tip and a wider root than the smaller pressure angle.

The designer evidently has here a certain choice in tooth de-

Fig. 3. Stub Tooth Superimposed on Standard Tooth.

sign in choosing between these various possibilities. The design must be a matter of judgment, experience, and, so far as possible, research. The introduction mentioned certain desirable qualities. Among these, the quality of quietness cannot be secured if there is vibration, hence the angle of action of one tooth must be such that

Fig. 4. Standard Railway Gear and Pinion.

it will not leave contact before its following tooth has entered. If it does, action of the gear set will be jerky, causing vibration and noise together with wear and other undesirable qualities. As involute teeth mesh, the contacting points of their surfaces roll and slide together, at such a rate as to produce theoretically uniform

rotation of their pitch circles. The more a gear tooth is stubbed (See Fig. 4) the greater will be the percentage of rolling of the contacting surfaces. This is considered desirable for reducing friction, and therefore wear, and consequently promoting smoothness of operation. It is true that the worm-gear tooth action is all sliding and is very smooth in its operation but its efficiency is low, and the unit bearing pressure and rubbing velocity of the sliding surfaces should be low. This results in large worms for comparatively small powers. Angles of action alone, as well as other features, would not permit stubbing teeth excessively to increase percentages of rolling. Stubbing teeth too greatly would tend to decrease wearing surface.

The standard 14½-degree involute tooth was among the first in the field. It was, and is, rotary cut and, since the milling cutter must clear itself, the tooth contour was modified decidedly, due to undercut in small numbers of teeth. This modification consists in filling in the flank of the tooth and relieving the tip. A certain amount of relief cannot be said to be objectionable, since it eases the teeth into mesh. If involute curves could be generated theoretically perfect, the relief would still be desirable, since teeth while under load unavoidably tend to deflect some small amount. This relief should be only sufficient for such functions and not dependent on cutter requirements.

Later the Nuttall 20-degree stub system and the Fellows 20-degree stub system were brought out. The Fellows is more largely used for the small pitches, the Nuttall for the large pitches. With the advance in automobile design, long and short addendum teeth came into prominence. At the present time various combinations of these often mutually contradictory qualities thus briefly described and outlined are advertised and offered the trade.

In the last few years, Nuttall engineers have been studying the manner in which the tooth should be placed on the face of a gear. Spur, stepped and herring-bone gears are well known to all having anything to do with gearing. Herring-bones in particular operate with peculiar smoothness, and are stronger than spur-gears of the same tooth dimensions. They have disadvantages in wearing where there is external end-thrust; in the gear being unable to slide by the pinion; in extra width of the face

due to the necessary center groove for manufacturing. Also, it is difficult to synchronize the two helixes properly when cutting. Their smoothness of operation was long supposed to be due to actual tooth overlap and consequent pitch-line lock; that is, there were always teeth in contact at the pitch lines. Low-angle helicals were not employed as they necessitated wide faces for tooth overlap and it was furthermore supposed that the unbalanced end-thrust due to the single helix, would be excessive. However, experience has shown that a low-angle helical gear not necessarily having overlapping teeth gives smoothness and quietness of opera-

Fig. 5. First Street-Railway Helical Gear.

tion. Fig. 5 shows the first street-railway helical gear. The set ran 500,000 car miles, is less than one-fourth worn, is still running, and has at least doubled car mileage on the pinion. Just as it is difficult to visualize the advantages of the long and short addendum, so with the helical gear. Apparently, however, the helix permits a minute section of tooth face and a correspondingly minute load to enter engagement, the load picking up as the face in mesh widens out, thus preventing tooth deflection.

The superiority of this gear was first thoroughly proved in railway service and for the last few years this type has been placed in all sorts of industrial service. The end-thrust previously mentioned for the usual 7½-degree helix angle, varies from 10 to 13 per cent. Where this is too great, a smaller helix angle is selected. There should be some provision for end-thrust. Usually this is found in collars already on shafting or in the resistance of the rotor to leaving its magnetic center. When the helical gear was developed, the features of long and short addendum gearing, high pressure angle, and a certain percentage of stubbing were incorporated in the tooth in order to give it the advantage of these desirable qualities.

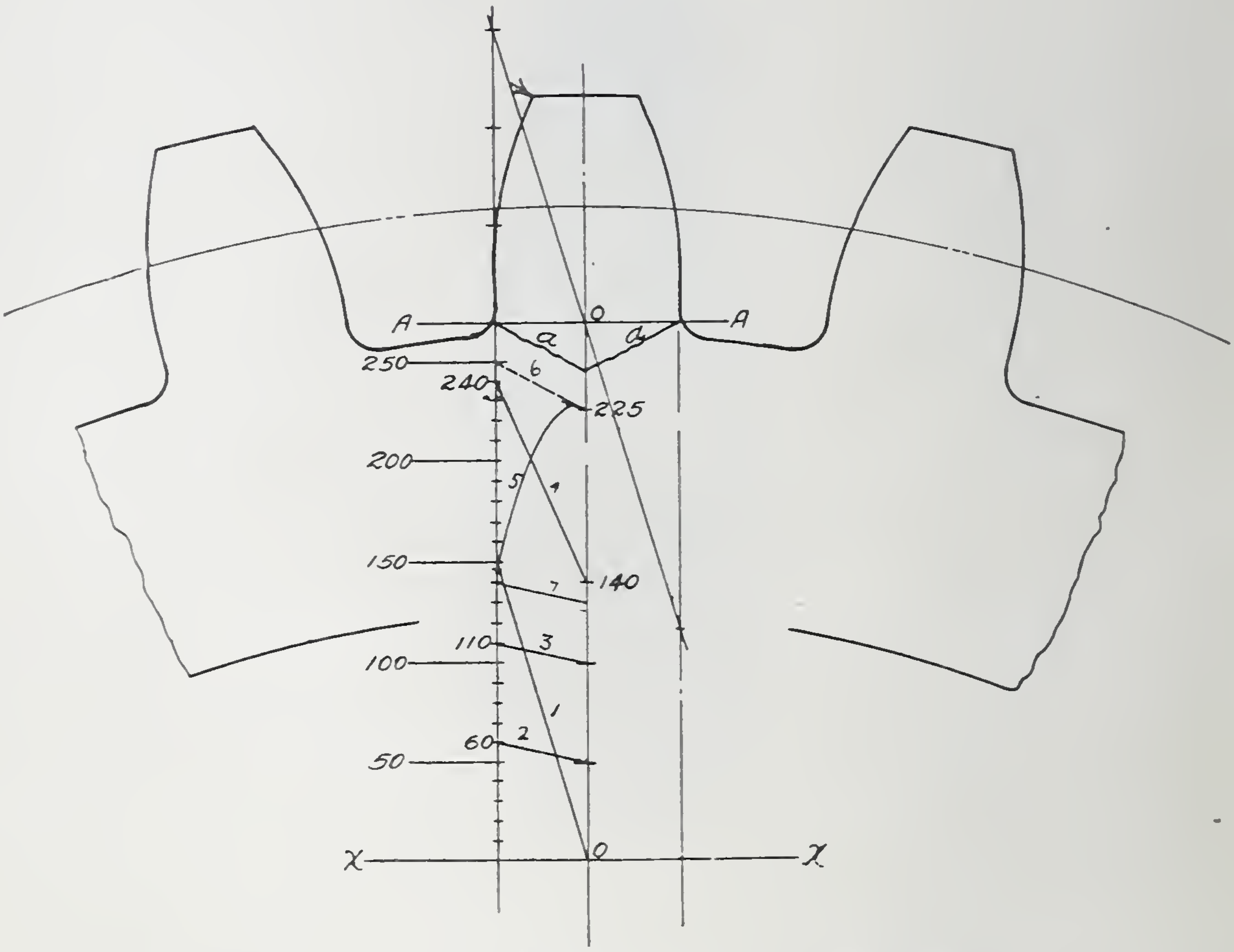

Fig. 6. Tooth Loading for Various Steels.

Those interested in gearing will realize that, in common with other mechanical details, standardization is of the utmost importance. Recent advertisements and trade publications might lead one to regard it as unimportant, but the technical and trade associations are working on this problem. All other things being even approximately equal, the prospective customer should insist on receiving a diametrical pitch standardized system.

MATERIAL AND HEAT TREATMENT

It will only be necessary to discuss briefly the material going into the gear, and its heat treatment.

The tooth being loaded as a cantilever beam, the grain structure in the raw material should be radial if possible to give the tooth the benefit of the full strength of the steel. This is being accomplished to some extent in the upset hammer-forged pinion, and to a greater degree in the drop forging. The forged and rolled steel gear blank is also produced with this radial grain.

When castings are used, especially when they are heat treated, clean steel is necessary particularly at vital sections. With heavy masses tied together with thin sections, a surprisingly small flaw will cause failure of the piece in heat treatment.

Referring to Fig. 6, it can be seen that the tooth is joined to the heavier mass representing the body of the gear across section *AA*. Any structural changes involving heavy internal stresses at this point will seriously impair the strength of the tooth which is stressed most heavily across this section in performing its work. This condition has eliminated alloy steels in heavy gearing, since they fail through fatigue indicated by *aa*.

Both by estimation and failure of steels in certain services curve *3* has been established as the stress curve on a certain gear, the maximum stress occurring at *C* dropping to *O* at the neutral axis and going into maximum compression at *C'*. Curve *1* is an untreated steel in this service, failing almost immediately through fatigue, the surface and the material to a considerable depth being stressed beyond the ability of the steel to carry the load. Curve *2* is a 40 to 50 carbon, oil-treated steel failing almost as rapidly as curve *1*. Curve *3* is a 55-65 carbon, oil-treated steel failing in the same way but much more slowly. Curve *4* is the ideal steel to resist just such a load as shown by curve *3*. Its strength is proportional to the load it has to carry. The grading off in strength and hardness reduces the heavy initial stress that must be set up when a steel is hardened uniformly throughout. Its maximum strength is ample to carry the peak-load. Curve *6* is an alloy steel showing but a slight drop in hardness and strength through the section. While the apparent strength should provide ample margin over the tooth loading, the initial stress in the steel drops

the effective strength below curve *3* at the surface, thus starting fatigue which progresses rapidly. The dotted curve shows the difference between actual strength and internal stresses.

An effort is being made at this time to duplicate curve *4* with an alloy steel by selecting an analysis that drops the carbon with respect to the eutectoid point in proportion to the carbon steel of curve *4*. It can be seen that any curve crossing curve *5* represents a steel that has fallen below the actual tooth stress required in this application.

This form of heat treatment, which grades the structural

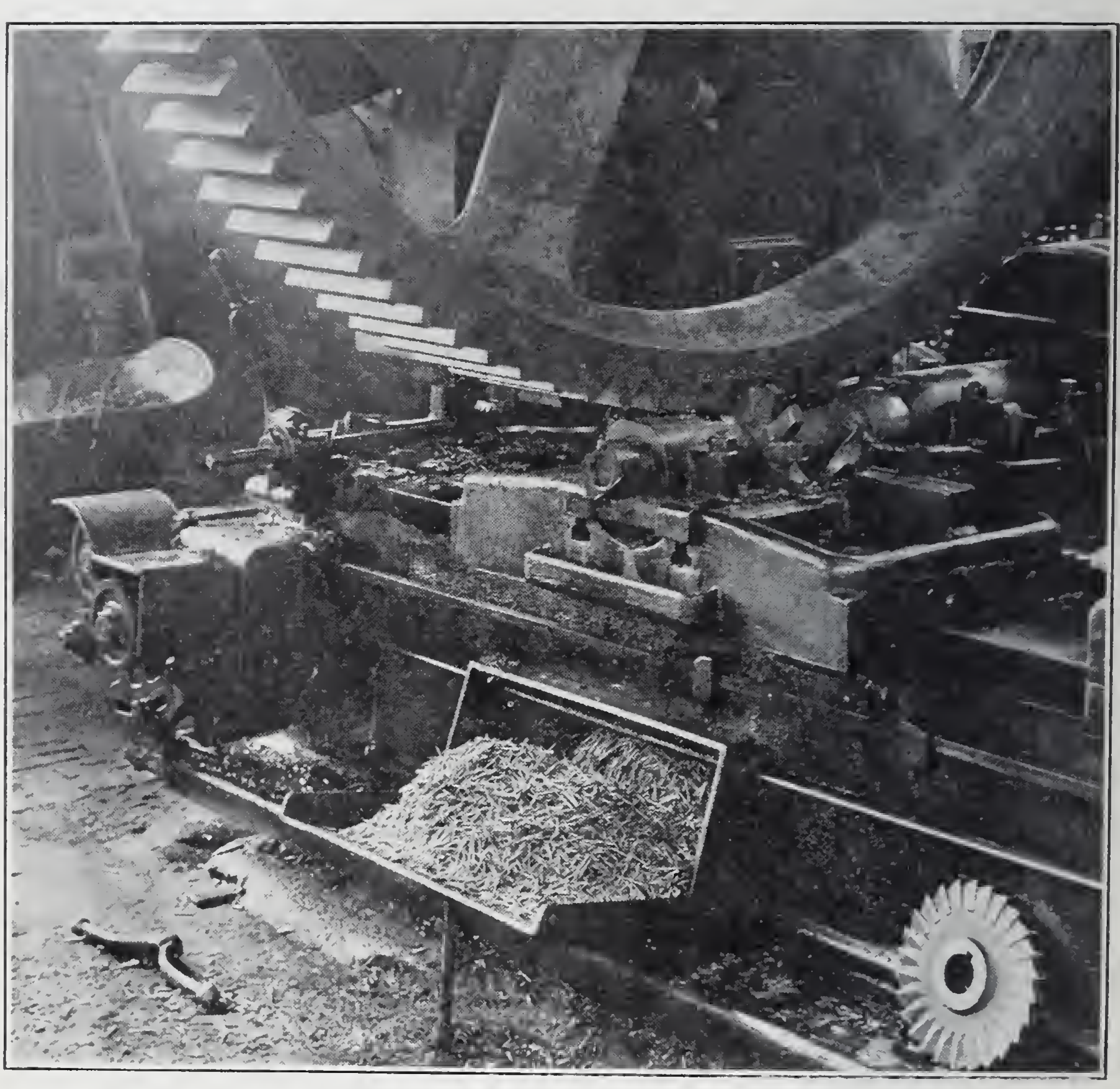

Fig. 7. Milling Cutter Cutting Gear Teeth.

change, permits the successful handling of large masses. Gears up to 10 feet in diameter, weighing 14,000 pounds, have been successfully treated, showing Brinell hardness limits of 364 to 477.

MANUFACTURING

This subject will be confined exclusively to involute teeth, cycloidal teeth being almost always cast or form cut.

The forming process was first in the field. A planing tool is compelled to cut the elements of the tooth contour while following the prescribed path of a former. At the completion of one tooth the blank is rotated into the proper position to cut the succeeding tooth, this being known as indexing. Another method of forming consists in the use of a form cutter, the shape of the tooth space

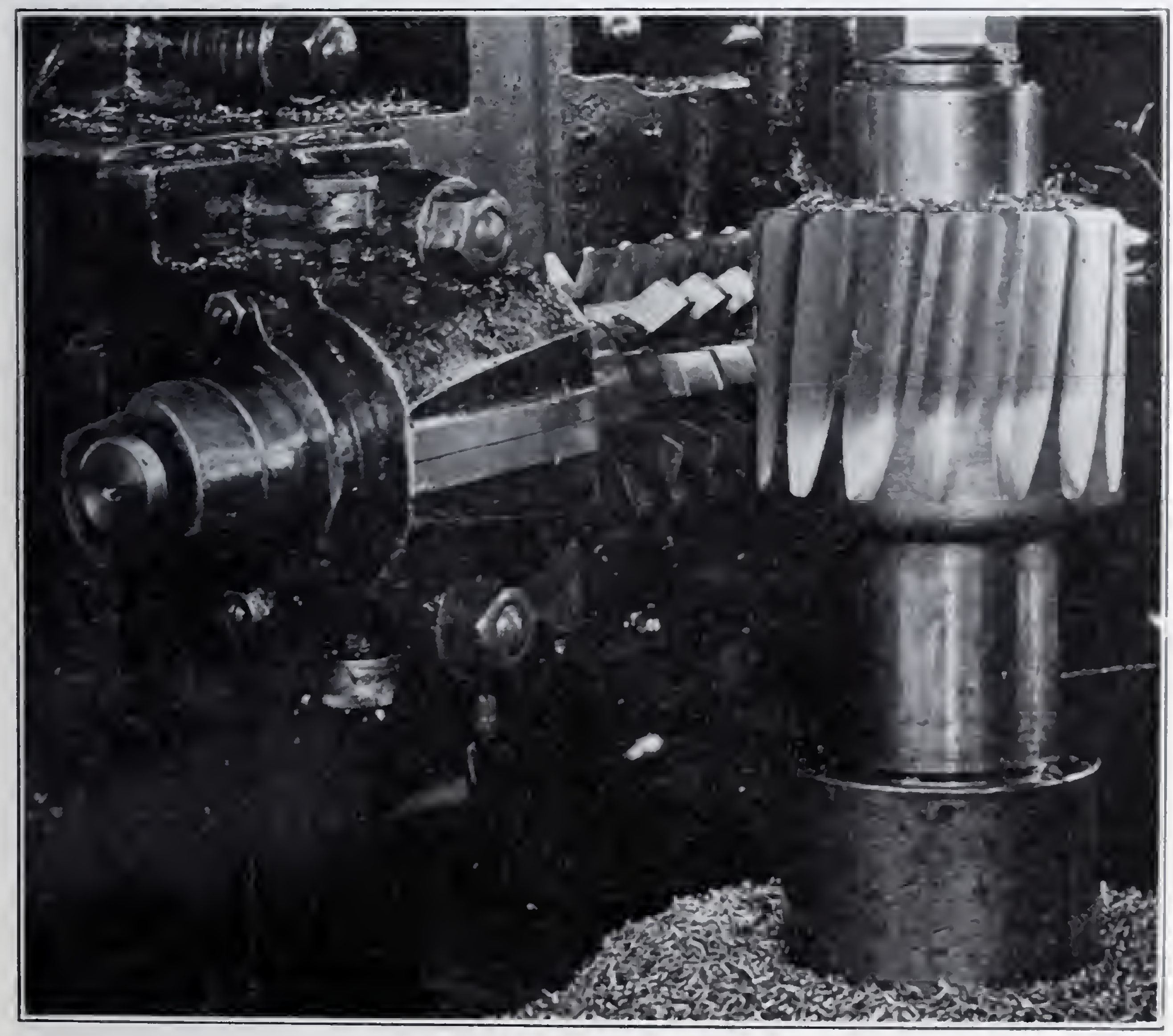

Fig. 8. Hobbing Machine Generating Pinion.

being used for the contour of the cutter. This is a straight milling process and requires indexing between teeth. Fig. 7 shows this process as normally carried out.

The modern practice is to generate chiefly by the hobber, and less frequently by the rack planer, or Fellows gear planer. Fig.

8 shows a pinion being generated by a hobber. The Fellows gear planer and the hobber, as will be explained later, require no indexing. The essence of the advance is that the accuracy of the gear produced has been transferred to controllable, mechanical movements in a machine.

In the forming process, the accuracy depends both on the machine and on the tool or former having a curved contour, difficult to make. With the exception of the Fellows, the cutters of generating machines are all straight-sided racks or rack wound on a helix with straight-sided flutes, this last being known as a hob. The Fellows generates a gear using a pinion cutter which is itself generated with a straight-sided grinding wheel. The principle underlying all such machines is that when the pitch-line of a rack cutter rolls tangent to the pitch-line of the gear being cut, at the same time feeding across the face of the gear in such a manner as to remove metal, the straight-sided rack teeth generate involute teeth on the blank.

A rack planer requires machine indexing, since the blank soon rolls off the rack; but with the Fellows gear planer this is unnecessary due to its circular construction; the hob needs none since the rack, wound on a helix, continually presents new teeth to the blank as the two rotate in synchronism. The hobber employing the milling process without indexing is the modern and ideal way to cut gear teeth.

Certain errors which creep into modern gearing must be discussed. Heat treatment causes varying amounts of warpage and shrinkage of gear rims. This increases backlash allowances. It throws the teeth out of position and changes tooth contour. The extent of the error depends on the material and on the process of heat treatment. The amount of the error can be controlled by proper manipulation. Regardless of the perfection of the "green" gear, only careful inspection will insure quietness or smoothness of operation of the heat-treated gear. This is not an argument against careful machining of the green gear, neither is it an argument against heat treatment. It is an argument, however, for careful inspection of heat-treated gearing.

Other errors are those due to inaccuracy of formers, rotary cutters, or generating tools. These may be errors of contour, of pitch displacement, of size, of inclination of tooth, etc.

There are errors due to indexing in formers and rack generators, and in the hobber from the wind and twist of the chain of gearing driving the machine. This last is found in all machines, varying with the extent of the gear train. Inaccuracies of the parts of the machine, lack of strength and rigidity, failure to synchronize all movements perfectly, failure to set up the work and the tool properly, bent arbors, etc., all cause errors. Without question, the most unfortunate error is that of pitch displacement. It causes interference, with clash, noise, vibration, non-uniform velocity ratio, etc., between two gears of a set, as their teeth fail to mesh properly.

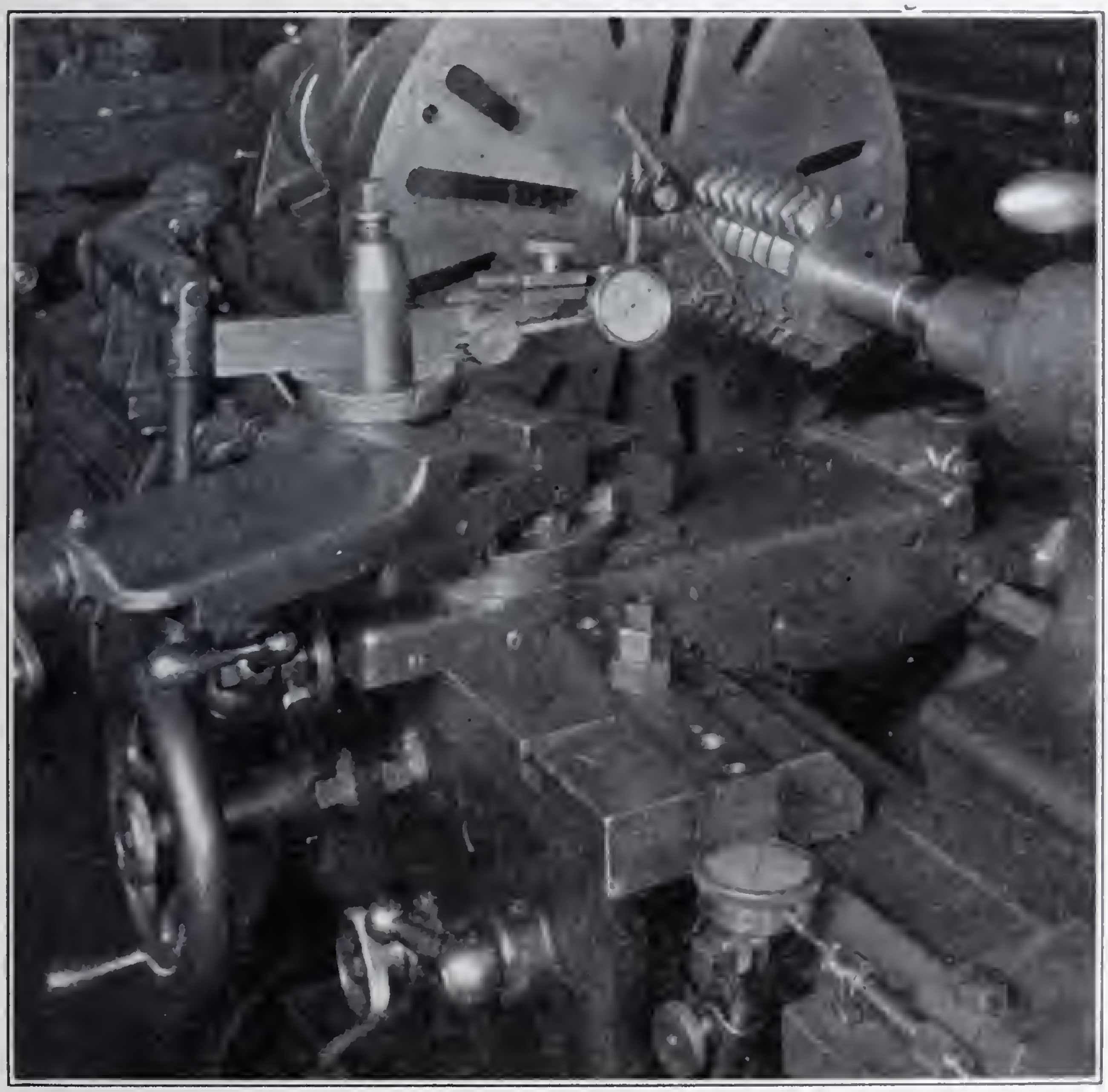

Fig. 9. Device for Accurate Gear Cutting.

A strong, rigid, accurate hobber, together with an accurate hob, will cut teeth second to none. The machines are continually

in process of improvement with prospect of great advances in the immediate future, especially with regard to the gear train, strength, rigidity, and accuracy. However, to overcome the errors above mentioned and make the gear more closely approach the ideal, the gear grinding process is being developed. Mechanically this is no different from the cutting process. There are form grinders, the grinding wheel being the contour of a form cutter, and there are generating processes employing the rack principle. The essence of the advance is found in the possibility of roughing out the blank in the green state, and finish grinding, whether in green or heat-treated state, under a light load. This permits fine finish and great accuracy. The gears are ground from the bore, thus insuring accurate involute action when finally mounted. Here, again, the final action will depend on the accuracy of the machine and grinding wheel.

INSPECTION

The foregoing discussion shows the necessity of careful inspection. The tools must be inspected first of all. The hob being the modern tool will be used to illustrate how carefully this inspection is made. The hob is mounted in a lathe on an arbor and carefully centered and lined up with the tool-post carriage.

Many devices for hob inspection are being offered the trade but none is needed. As shown in Fig. 9, there is an indicator with a ball point placed in the tool post. Also there is a finger which acts as a stop against the front of the flute. The indicator is placed on the front edge of the hob flute and the exact location thereof determined by vernier and indicator to the right. The indicator is then swung back on its hinge, the tool carriage moved to the right, the stop and indicator placed against the next flute along the gash and the vernier again read. To measure from flute to flute in the helix the same procedure is followed. The eccentricity of a hob is determined by indicating the collar at the hob end, and then the toplands of flute at the cutting edge. If this eccentricity is in thousandths, the cam of flute relief is such, the error of pitch displacement due to the gashes not being of a uniform angular placement on the circumference, may be safely neglected and the lead of successive flutes in the spiral measured

as already outlined. The pressure angle of the sides of the flute can be measured by swinging the tool rest to the proper angle and feeding in the indicator point. These readings can be charted to produce the exact contour. This will also show whether teeth are inclined or not. Hobs can now be secured accurate in all ways to 0.002; ordinarily, it is not essential to keep them so close.

The machine accuracy can be tested by the apparatus of Fig. 10. This figure shows a spur-gear on a hobbing machine. The rotary cutter shown on the tool arbor was inadvertently left from

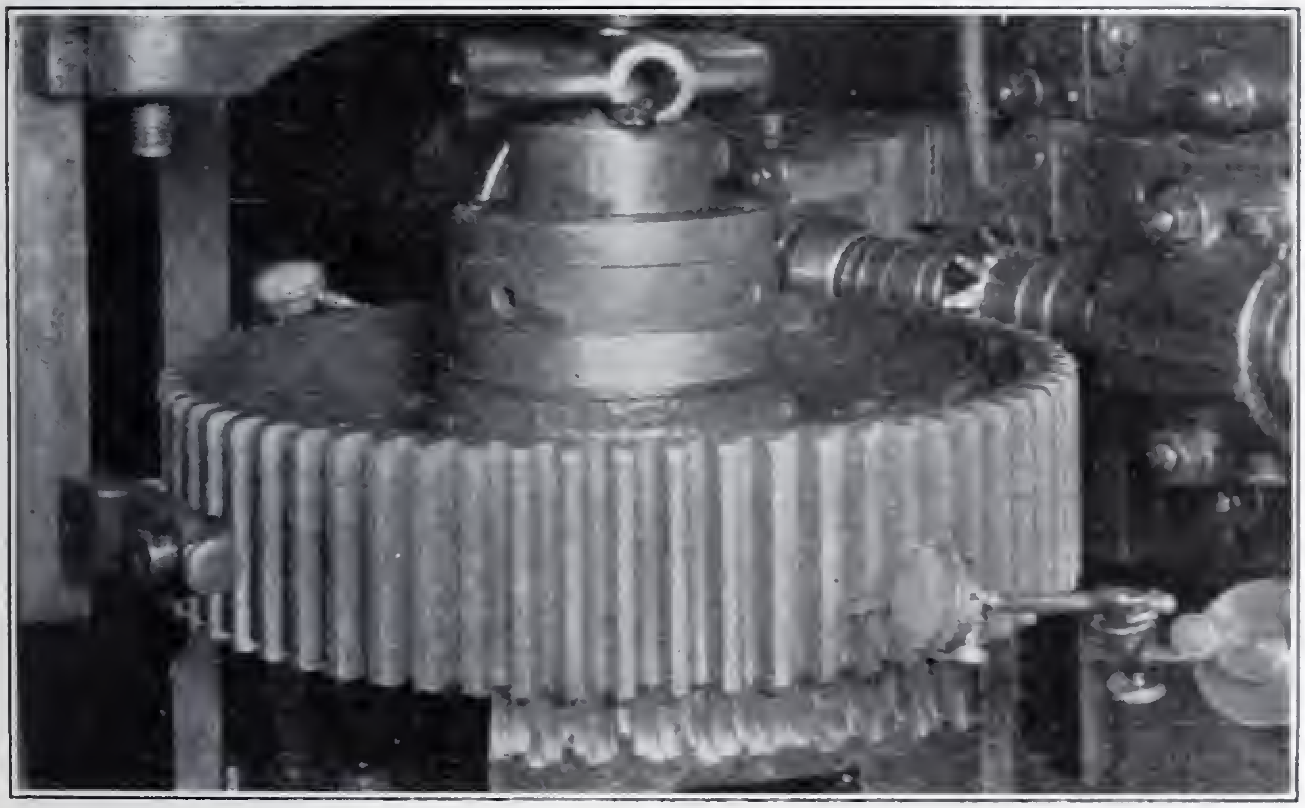

Fig. 10. Device for Testing Accuracy of Hobbing Machine.

another job. This set-up was taken for illustration only. A gear is cut by a hob as nearly perfect as possible. The teeth are indicated in position on the machine at 0 and 180 degrees therefrom for pitch displacement (See indicators on Fig. 10). This is done at intervals around the gear or with every tooth in bad cases. If it checks all right, the only essential test is to determine whether the lead screw is uniform. This is done by noting the uniformity of movement of the tool arbor support on the column at different positions. At the present time, certain special devices are on the market but the foregoing are as accurate as any. Sometimes the work-table worm wheel will check perfectly but the gear cut will be out of pitch. Then the trouble must be looked for in the driving

worm, in a bent arbor, or the other usual inaccuracies of machine-tools.

The gearing itself must be inspected when cut. Different types of gears demand different types of inspection. First as to accuracy of tooth contour, this may be established by special involute contour instruments. They work on the principles of involute tooth generation. It is not thought essential to discuss them here as those interested can secure information quite readily. To measure pitch displacement, the method shown for machine measurement of the table worm wheel can be utilized. There is also a tool which measures from tooth to tooth, measuring by the involute curve properties.

The final inspection of gears is as follows:

Spur-gears are checked for tooth thickness and addendum by use of tooth verniers or gages on small jobs. On quantity jobs, the gears are run on fixed centers. Special test machines are used together with an indicator to check eccentricity, thin and heavy teeth, errors of indexing, interference, bearing alignment, run-out, etc.

Bevel-gears are checked in a similar manner for tooth dimensions. They are checked on a surface plate for shaft angles. The center distance from the backing of the bevel-gear on a surface plate to the center of bore of the pinion in mesh therewith is checked. This is important and should be insisted on by prospective customers. While still set up, the face alignment is checked.

Helical and herring-bone gears are checked in a similar manner to spurs. The pinion face is left long in herring-bones to take care of pitch displacement errors and when aligned up the extra face is removed.

Worm and worm wheels have teeth and threads checked for dimensions similar to spurs. The worm is seated on the wheel and checked for center distance, misalignment, angle of the meshing teeth, lead of the worm, and central position of the worm on the worm wheel. Where the quantity justifies it, this is done on centers.

INSTALLATION AND MAINTENANCE

A gear is designed to have the entire width of face carrying the load. Misaligned or inadequate bearings tend to localize loading and, while the gear quickly adjusts its face by rapid wear to take care of these conditions, fatigue may have been started which will ultimately cause failure.

Any tendency to wear ridges on gear teeth should be eliminated, since riding on this ridge of the meshing member causes heavy localized loading. It is essential to maintain proper depth of meshing. Meshing too close on centers causes wedging of the teeth resulting in enormous loading.

When fly-wheels are part of the equipment, figure what it means in overload stress to buck the motor. When flexible couplings are installed on both sides of the gear reduction, they relieve the gearing, but often to their own detriment.

Proper lubrication is good economy and it pays to watch the accumulation of dirt and grit in the gear-case and clean the case periodically. In street-car service, as high as 35 per cent. of grit has been found in a supposedly well lubricated gear-case.

CONCLUSION

The foregoing discussion has been a brief resumé presented in as non-technical form as possible, of the most recent developments in the art of gear design and manufacture.

DISCUSSION

Mr. E. E. Espenschied:* In the automotive industry the bevel-gear and the worm gear are both used. I would appreciate some information as to the relative values or advantages of the two types for the automotive industry—a little insight into why one is used in one place and one in another.

Mr. W. H. Phillips: There has been a great deal of controversy over this subject and I do not want to get into an argument over the relative merits of the bevel-gear and the worm gear in automobile drive. It is known that there are many arguments in favor of either one. There are certain conditions that favor the worm drive and certain conditions that favor the bevel-gear. There has been a great deal of argument pro and con as to the relative efficiencies of the two. Due to the advent of the higher grade worm gear and its careful installation it has been very materially improved in its efficiency—certainly to the point where it is giving the bevel-gear much competition in automobile drive.

Mr. K. T. Stearns, *Chairman*:† I would be interested in knowing whether the long and short addendum principle has been applied in the design of bevel-gears.

Mr. W. H. Phillips: Yes. There was no reason why it should not be. While the long and short addendum gear in industrial service is relatively new, it is being applied to beveled gearing at the present time. The automotive bevel is of such design.

Mr. J. R. Cline:‡ In the making of large gears are the teeth sometimes made eccentric instead of being concentric? In a large gear of a certain type it was advertised that the gear was eccentric in eight points instead of being concentric.

Mr. W. H. Phillips: Are you referring to a heat-treated gear?

*Representative, Commercial Truck Co., Pittsburgh.
†Engineer West Penn Power Co., Pittsburgh.
‡Practice Man, Universal Portland Cement Co., Universal, Pa.

Mr. J. R. Cline: No, it was in the machining.

Mr. W. H. Phillips: As far as our practice is concerned we are having a hard enough time keeping gears concentric. I can not see any reason for making gears eccentric. There may have been some special application where it may have been desirable to perform the functions of a cam rather than of a gear in making the gear eccentric at eight points, but for a correct theoretical gear for power transmission I can not see any reason for it.

Mr. J. R. Cline: There was no reason given for it. It was just for some special case where it acted as a cam, as you say.

Mr. W. H. Phillips: It certainly could not be accomplished without altering our present gear-machining equipment.

Mr. W. M. Austin:* It appears to me that with a 15-degree involute gear, a short addendum on one gear and a short dedendum on the other would give results similar to what were shown with respect to the 20-degree involute gear. In fact, the length of slide between the teeth ought to be less with the 15-degree involute gear than with the 20-degree, thus giving a higher efficiency for the 15-degree involute than for the 20-degree involute gear.

I have always been under the impression that the only gain of the 20-degree involute over the 15-degree involute is in greater strength of teeth, and in the fact that it is possible to get continuous perfect tooth action with a smaller number of teeth on the gear. It is, of course, true that in the Brown & Sharpe interchangeable gears from 12 teeth to a rack, the points of the teeth have to be made narrower than the true involute would make them in order to prevent interference. This results in the tooth action ceasing before the ends of the teeth are reached, except where two gears, both having a small number of teeth, run together, in which case theoretical tooth action is not continuous, and the motion of the driven gear is bound to be jerky.

*Electrical Engineer, Supply Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

If a 20-tooth involute interchangeable system were used, the correction for interference, if any, would be much less than with the 15-degree involute, and perfect tooth action could be had with a less number of teeth on the meshing gears than with the 15-degree involute.

With respect to the previous question about a gear cut with eccentric arcs; if these arcs correspond to the portions of the rim between the arms, when the gear is running under load, the reaction tending to force the gear and pinion shaft apart might spring the eccentric pitch-line into a position concentric with the shaft. I can see no advantage under ordinary conditions, and, if the gear were not fully loaded, the teeth would crowd, and an excessive frictional loss would result.

Mr. W. H. Phillips: You refer to the 20-degree and the 15-degree pressure-angle standard and not to the special design with long and short addendum?

Mr. W. M. Austin: Whatever you say about the long and short addendum, the 15-degree would be the same as the 20-degree. When you make them both alike it would be possible to get less length of slide on teeth of the same pitch in both cases, the same arc of pitch and recession in the two gears, but one is short and the other long addendum, so that the load is carried on the tooth sliding on the other and rolling to a certain extent. If the number of degrees on the pinion and the corresponding ones on the gear were the same on the 20-degree and the 15-degree involute, would the slide be less on the 20-degree involute? That is the impression I got.

Mr. W. H. Phillips: Mr. Burnham should get into this discussion, and I think he can answer this question.

Mr. L. F. Burnham: Provided you use the involute portion of the 14½-degree tooth, all other conditions being like the 20-degree, there would be more sliding than with the 20-degree. But there is also trouble with the 14½-degree in that it has been corrected and there is an appreciable portion at the top of the

tooth which is relieved that can not be said to have either rolling or sliding action at first. Examination of an old tooth will show that there has been contact. Such action would be mostly slide. It would wear the tooth. It would not wear as uniformly as the involute portion. We will not consider this relieved portion but just the 14½-degree and 20-degree, and the 14½-degree will have more sliding; but we use the long and short addendum and by so doing we are able to get still greater rolling with the 20-degree tooth. In the involute zone of the 14½-degree, tooth rolling nearly approximates the 20-degree tooth but there is only a small portion of involute in the tooth, not more than 50 to 60 per cent. That is due to the fact of the relief in the 14½-degree. In the 20-degree we get nowhere near the same amount of relief.

MR. W. M. AUSTIN: There is no contact between the gear and the pinion in the undercut?

MR. L. F. BURNHAM: Examination of an old tooth will show that there really is contact. To clear up this discussion, I will add another diagram and discussion at this point. Referring to Fig. 11, a 14½-degree and a 20-degree gear set have been drawn up to show relative rolling and sliding. In both cases, 15-69 ratio was selected and 1 pitch to get the figure of a suitable scale. The position of pitch-lines, root circles, and addendum circles, are identical; therefore the base circles are not identical. This is the proper way of comparing the relative merits of pressure angles, for we can have no pressure angles until we have gear sets and we should compare similar gears. Gear and pinion contacting surfaces are shown. That is, section *1* has contact with section *1*, etc. The length of sections on pinions are alike except for section *B*. In each case, the mating gear sections are determined. The figure shows that the corresponding 14½-degree gear set sections are not so nearly of a length as are the corresponding sections of the 20-degree gear set. That is, there is less roll on the 14½-degree set than on the 20-degree set. Also this condition becomes worse as we recede from the pitch-line either way. The 14½-degree set shows the useless portion of the gear tooth, plainly. It is clear that although stubbing the tooth would increase rolling of both sets, relative advantage would be as before. Stubbing the

gear on the 20-degree set and filling in the pinion space correspondingly will evidently increase rolling properties. Such a design is known as a long and short addendum gear. Both gear and pinion may be stubbed, thus utilizing only the more favorable portion of

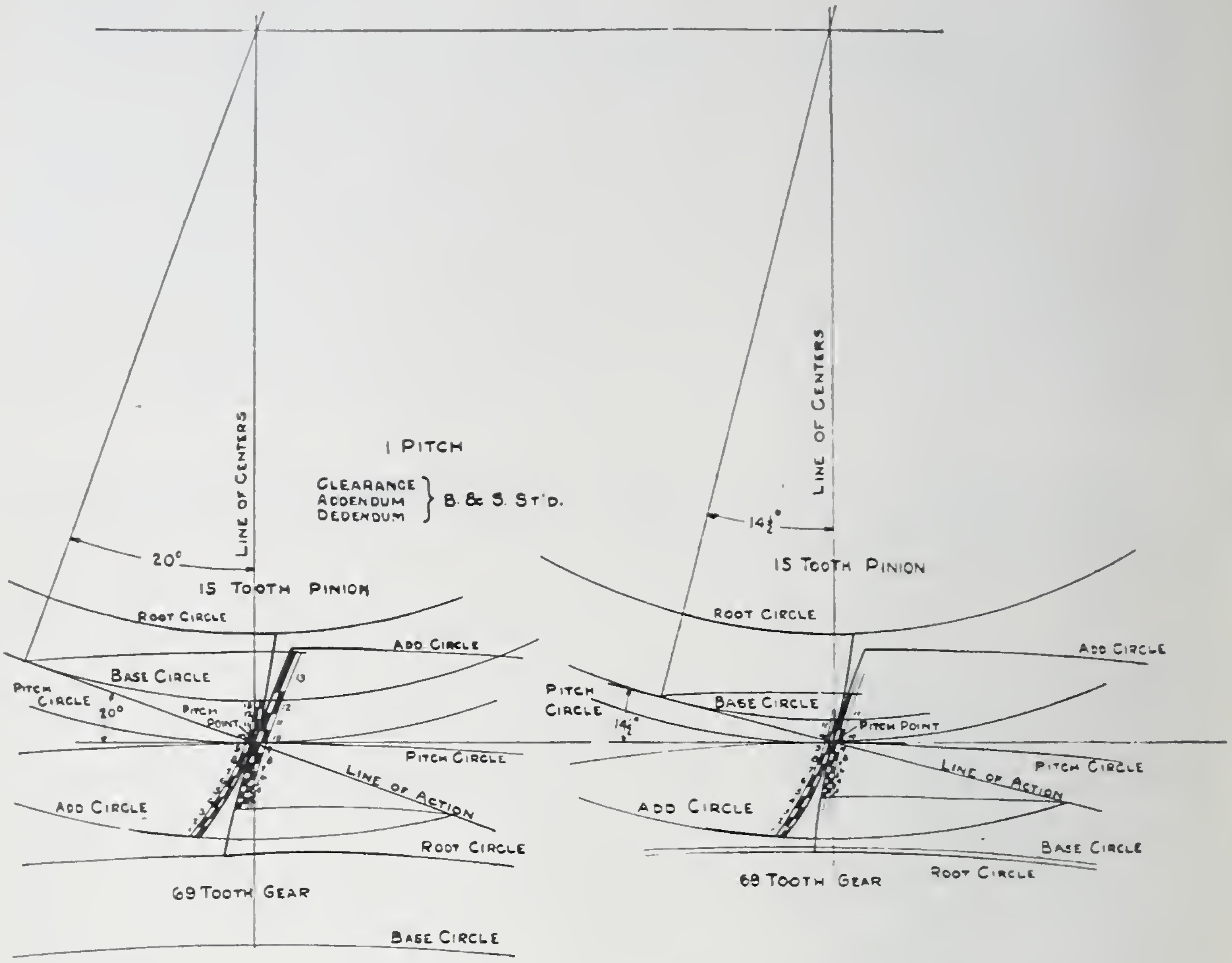

Fig. 11. Outlines and Positions of Involute Gear Teeth.

the involute. While it is true that the involute on the 14½-degree gear set is straighter than on the 20-degree set, a study of the two lines of action shows why there is more rolling on the 20-degree set than on the 14½-degree set.

MR. G. E. FLANAGAN:* I do not know whether it is just fair to start a controversy as to the theoretical merits of the circular and chordal pitch of the gear. In the old days there was a great deal of argument that one was theoretically correct and the other was not theoretically correct. I would like to hear the speaker's opinion.

*Mechanical Engineer, Heyl & Patterson, Inc., Pittsburgh.

MR. L. F. BURNHAM: I do not know that I exactly understand the question.

MR. G. E. FLANAGAN: The pitch of the gear is the distance measured along the arc of the pitch-line, either in the gear or pinion. Take the chordal gear, the pitch is the distance straight from one tooth to the other. In two gears, both materially different sizes, the pitch would be different. If you measure on the chord you get a different arc pitch.

MR. L. F. BURNHAM: We measure our gears on the chord. That is necessary from the construction of the verniers. We know that in that way we get the active tooth. But the circular dimensions are accurate, just as are the chordal. I do not think it matters which way you measure. All gear systems that I know of at the present time are laid out on circular pitches, but they are necessarily measured by chordal pitches.

MR. G. E. FLANAGAN: Which is theoretically correct? It is not a question of measuring. If you have a gear of three-inch pitch should not that pitch be measured along the arc of the gear, or should it be measured on the chord?

MR. L. F. BURNHAM: On the arc.

MR. G. E. FLANAGAN: That is the question. If you go back to Nystrom's book,* he claimed that gears on a circular pitch did not mesh well together. A man who reviews that book takes pains to say that he does not agree with Nystrom. That is the reason I raised the question as to which is theoretically correct.

MR. L. F. BURNHAM: I don't believe there can be any question about measuring on the chordal dimensions not being the proper way, due to the way an involute is generated on a base circle and the action of two mating involutes depending on the location of the base circles only. The pitch-circle is a function of

*"Nystrom's pocket-book of mechanics and engineering," by John W. Nystrom. Ed. 19, revised and corrected by W. D. Marks. 1887. Lippincott, Philadelphia.

the base circle and pressure angle. We cut involutes on a given circle and, the circle and the base being fixed in any gear as regards each other, if the involutes are rolling together properly I know the involute, whether generated on a large or small gear, must be correct, if it is generated on a circular and not on a chordal pitch. I would say that the pitch would be correct only if measured on a circular arc. I do not see how it could be correct if measured on a chord.

MR. G. E. FLANAGAN: It might be interesting to explain to some of us just what the process of heat treating gears consist of and what its limitations are as to size of gears.

MR. W. H. PHILLIPS: Both cast-steel and forged steel are now being treated in industrial gearing. Most cast-steel is acid open-hearth, and we are successfully heat treating the acid open-hearth carbon steel down to as low as 0.28 carbon, producing over 400 Brinell hardness without causing excessive warping by quenching rapidly. I do not want to get into a technical discussion on the metallurgy of heat treatment; but, very briefly, the theory of quenching is simply this:

We have a casting or forging which is called a pearlitic steel, in which our carbon is combined chemically with three parts of iron (cementite) and again mechanically with seven parts of iron which, in turn, is distributed through the rest of the iron as a network. This is pearlitic steel. In heat treating we heat it up to a temperature, known as the critical temperature, at which temperature the carbon goes into solution in the iron. If it is cooled down slowly it comes back into the pearlitic state. If we cool it fast enough we can hold the carbon in solution in the iron, getting a solution of carbon and iron. We can cool a 300-pound gear of 100-carbon steel in oil in eight minutes and get 500 Brinell hardness. We have found that at that point you eliminate your wear as a serious factor. Now we have practically a tool steel. If we cut down that carbon content, still maintaining the hardness, we get a solid solution of iron and carbon with smaller percentages of carbon in the solution, giving a tougher steel. To harden this steel, however, we have to increase the speed of quenching;

and we have succeeded in cooling these 300-pound gears in water in three minutes. We have gone still further and quenched in a special solution in a minute and a half, and on account of that very drastic quenching we can drop our carbon content to as low as 0.28.

This, we have found, is the most successful heat treatment for most classes of industrial gearing, giving a very tough gear, with a low carbon content and a high surface hardness. Its resistance to fracture under impact is enormous and its hardness is still sufficient to maintain a low percentage of wear. In fact, it quadruples the life of the untreated gearing. On a casting it will increase the life 3½ times. These figures are pretty well established through years of following up the heat-treated gear in service.

One of the difficulties that confront us in the heat treating of industrial gears is that many gears were designed merely to carry the load, without regard to how we blend our light and heavy sections and what the stiffness of the gear is, and as a result when some of these designs are put through the quenching operation we get distortion or set up enormous strains.

Properly designed gears up to 10 feet in diameter and weighing up to five tons, can now be very readily heat treated. This is our maximum capacity at present. At the present time we are contemplating treating them up to 15 feet in diameter. The saving is obvious, especially where the gear is subjected to severe service. Considering the importance of keeping the equipment running, when a shut-down would mean serious loss of production, the slight increase in cost over the untreated gear pays for itself many times over.

BOOK REVIEW

By W. E. Mott*

The Young Man and Civil Engineering. By George Fillmore Swain, xi+203 pp., 1922. The Macmillan Company, New York. $2.

Much has been written about the turn-over in labor. It is a well recognized factor in the cost of production. Plant managers and personnel officers have done their best to reduce this source of economic waste.

There is another kind of turn-over which is familiar to educators, but which is not recognized as such by the general public.

Jones learns that Smith's boy has come home from college in the middle of the year and gone to work. Jones' comment is short and sometimes to the point—"Too much football" or "Had a row with the college authorities."

It is easy to blame the boy and he is usually chagrined himself and his pride has been so hurt that he will not "hit back."

The financial loss involved in such educational fiascos may fall where little harm is done, but in many cases real hardship results, to say nothing of disappointment and even heartache at home.

Blame the boy? Yes but what opportunities were afforded him whereby he could inform himself about the vocation or profession which may have struck his fancy? The members of his family or those upon whose advice he must depend are often as ignorant of such matters as the boy himself.

Fortunately, the freshman of the future seeking information on the choice of a career will have access to a group of books written by leaders in the various professions—a "Vocational Series", the third number of which deals with civil engineering. The author has long occupied a leading position in the educational world and has been honored by the members of his profession by election to the highest office in their gift, the presidency of the American Society of Civil Engineers.

Dr. Swain brings to his task a wealth of experience in advising and teaching young men preparing themselves for the engineering field and has himself attained eminence as a consulting civil engineer.

In the introductory chapter are set forth clearly and concisely the author's reasons for his belief that: "No profession is . . . more important for the welfare of the human race than engineering . . . None has done more to promote the well-being and to advance the best interests, material and moral, of the human family." Besides tracing briefly the history of the development of the many branches of engineering as they exist to-day, Dr. Swain emphasizes the fact that engineering, "broadly described as the science and art of construction," is really one of the learned professions. He points out that the engineer must recognize the economic questions involved in his work and accordingly suggests the following definition: "Engineering is the science and art of applying, *economically*, the laws, forces, and materials of nature, for the use, convenience, or enjoyment of man."

Chapter 2 entitled "Branches of Civil Engineering", includes a survey of the work involved under the following sub-heads: (1) Surveying and Geodesy; (2) Railroad Engineering; (3) Highway Engineering; (4) Hydraulic Engineering; (5) Sanitary Engineering; (6) Structural Engineering and (7) Municipal Engineering. This chapter will give the prospective student an excellent idea of the various lines of work which he may undertake. Under the heading "Qualifications Necessary or Desirable for the Civil Engineer," are set forth the professional and personal qualifications necessary for success in engineering work, or, as a matter of fact, in any field of human activity. Every young man could read this chapter with profit whether he plans to be an engineer or not.

Chapter 4 is entitled, "Education of the Engineer". After discussing, pro and con, the question of a four-year course in engineering or a combined collegiate and engineering training, the author states:

> "To the great majority of young men who wish to follow a career in engineering, my advice would be this: enter an engineering school as soon as you are prepared, and get the habit of *work* at once:— and not only the habit of work, but train yourself to work *effectively*. Hard work will not help you much if it is ineffective and does not lead to results."

This chapter is a distinct and forceful contribution to the literature dealing with the training of young men. In language

which cannot be misunderstood, and with all the weight of conviction resulting from a lifetime of successful educational effort, the author shows convincingly what is essential and what is superfluous in college training. He throws a new light on the so-called cultural work for college students. Every freshman should learn the following quotation by heart and never forget it:

> "You cannot become a specialist, or expert in four years. If you try to become an expert in college you will more likely turn out a sham or a narrow bigot. If you *aim* for culture you will be likely to turn out a conceited ass; if you *aim* for wisdom, you will be likely to turn out a pedant. If you work hard, take advantage of your opportunities, follow good advice, culture and wisdom will come of themselves in due time, if they are meant for you."

The fifth chapter discusses the "Characteristics of Civil Engineering as a Profession," and demonstrates that the civil engineering graduate has unlimited opportunities for advancement and public recognition if he will continue to train and broaden himself in after life.

"The Outlook for the Civil Engineer," Chapter 6, will effectually set at rest the fears of such young men as may feel that the profession is now, or soon will be, overcrowded. So much yet remains to be done in this world of ours that the young engineer will find no limits set to his field of activity.

This most interesting and stimulating book concludes with "Suggestions" to the student of engineering. It contains sound advice on self-training and cultivation, even on personal habits, how to get a job and hold one, how to become a man and play a man's part in the world.

The book is intended primarily for young men; but many older men, experienced engineers, will read it with pleasure and profit, thus enabling them to give better advice to the younger generation of engineers.

Dr. Swain has pointed out the road to success and his book should be read by every young man who contemplates entering the civil engineering profession.

PLANNING MASS TRANSPORTATION FACILITIES

By T. Fitzgerald*

OUTLINE

Conclusions.
Importance of Mass Transportation Facilities.
Foundations of Community Development.
The Object of Mass Transportation.
Factors Affecting Plans.
System Complicated by Fare Problem.
Influence of Topography.
Street Congestion and Rerouting.
Unified Political Control Essential.
Steam Railroads.
Types of Facility.
The Bus.
Railway Service Basic.
Separate Grade Terminals for Surface Cars.
Rapid Transit.

CONCLUSIONS

The mass transporation facilities of any urban district are vital factors in the life and progress of that district. They must be adjusted in capacity and extent to the present and prospective development of the community served.

Natural resources, external transportation facilities and topography are the principal material bases limiting community development.

The principal object in planning mass transportation facilities is to provide for transportation service in and between industrial, commercial and residential areas, which will stimulate, to the degree justified by present and prospective conditions, the properly co-ordinated development of these areas for that use to which each is best adapted.

Another important object is to provide for transportation service which will stimulate the orderly development of educa-

*Consulting Electric Railway Engineer, Pittsburgh.

tional, religious and amusement institutions and central community activities, by making them available to the whole population.

Mass transportation facilities for an urban district should include those types best adapted to the different traffic problems usually encountered in such a district.

Generally:

Trackless vehicles are best adapted to light-volume, short-haul, high-fare traffic.

Street railways are best adapted to medium-volume, medium-haul, medium-fare traffic.

Rapid transit (high-speed, large-capacity, separate-grade electric railway) is best adapted to large-volume, long-haul, low-fare traffic.

Planning a mass transportation system involves the co-ordination of these types of facility so as to apply to particular traffic movements the most economical and attractive type.

The various types of service must be auxiliary and supplemental to each other and not directly competitive.

No general plan for the large expansion of mass transportation facilities should be decided upon until after the most comprehensive and exhaustive investigation by engineers of experience in the design, construction and operation of all types of facilities.

Due consideration must be given to plans for community development adopted by representative bodies.

The importance of the problem and the consequences for good or evil to the community, which may result from good or bad planning for this vital service, demand the constructive interest and co-operation of representatives of all the interests of the entire community; social, political and business.

IMPORTANCE OF MASS TRANSPORTATION FACILITIES

Concentration of population in urban communities is introducing problems which appear more serious than any heretofore faced. Collective action for good or evil is more effective than individual action. Along with the evils of concentrated population, there are advantages which may be utilized to further the progress of society. These advantages come principally from the

better economic, educational, religious, amusement, and recreational institutions which can be supported by larger numbers of people acting collectively.

To take advantage of these opportunities for constructive collective action, requires a citizenship living in healthful homes and occupied in profitable work. The extent to which the citizenship of a community is healthfully housed and profitably employed, will determine the extent of their social progress. Unhealthful housing, and living expenses which wipe out the profit from work, cannot be the basis for constructive (and must be fraught with considerable danger in the direction of destructive) social effort. To the extent that better housing and employment opportunities are furnished by transportation, will the opportunity for progress be provided.

A most casual consideration of the problem of mass transportation, particularly for an industrial community, will convince anyone that the social, political and industrial health of that community is just as dependent upon its local passenger transportation facilities as the health of the human being is upon the free circulation of his blood.

Adequate personal contact between individuals and groups of individuals, made possible by adequate passenger transportation service, is a most important factor in the orderly political progress of a community.

Aside from the indirect benefits derived from better social conditions and a more enlightened electorate, there are direct, immediate and important benefits to industry from any sound improvement in the mass transportation facilities serving it. To illustrate the principal advantage:

Imagine two large industrial districts 10 miles apart, with residential territory between. Assume a connecting transportation system operating on a scheduled speed of nine miles an hour. Those persons served by this system living within 4½ miles (30 minutes) of either industrial center would constitute the bulk of the workmen available. There would remain one mile of territory midway between the two districts, the use of which for residents employed in either would be considerably restricted by the time required to travel to and from work. If the schedule speed were

increased say to 18 miles an hour, each industrial center could be reached in a reasonable time by workers living within one mile of the other. Such an increase in the territory from which industries might secure labor would greatly benefit industrial operations, and the larger opportunities for the sale of their services by working people would work to their advantage. The positive value of justified increases in the speed and capacity of transportation facilities has been shown by the results from the construction and extension of transportation systems in metropolitan communities. Try to visualize the labor and housing conditions which would exist in any of our large industrial districts, if the workers were compelled to live within horse-car distances of their places of employment. It is inconceivable that large commercial and industrial centers could function under such conditions.

FOUNDATIONS OF COMMUNITY DEVELOPMENT

Before proceeding with plans for transportation facilities, the extent of the present and prospective development of the district to be served must be considered.

1. The natural resources available, such as coal, oil, gas, ore and other materials. The volume and availability of these will limit the population which can be properly maintained in profitable employment.

2. The effectiveness of railroads and other external systems of transportation and communication must be taken into account, because on these depend the ability of the community to serve profitably the outside world.

3. The topography of the district must be adapted to the development of adequate residential areas accessible to adequate industrial areas within reasonable transportation distances.

The extent to which the topography permits the connection by transportation service of residential and industrial locations will govern the extent of community development.

THE OBJECT OF MASS TRANSPORTATION

The primary object of mass transportation service is to promote the orderly progress of a community in all of its activities.

To achieve this orderly progress, healthful and attractive housing conditions, educational, religious, and amusement institutions and other centralized community activities must keep step with industrial and commercial expansion.

By "mass transportation" is meant local "common carrier" passenger service, over regular routes, within urban or metropolitan districts.

The ideal mass transportation system would provide opportunity, through cheap and attractive service, for the whole population to make contact with and to support the economic, political, and social activities of the community served.

FACTORS AFFECTING PLANS

In trying to approximate as nearly as possible this ideal, careful consideration must be given the present and prospective transportation demand and the facilities in use and available for use in the community.

First come present traffic and present facilities. Careful surveys should be made of industrial development and the growth of residential areas in its support. Working places, homes, places of amusement, and all other factors should be carefully studied with a view to improving and adjusting present facilities as nearly as possible to the traffic demand.

In a growing community, such a study serves the additional purpose of supplying a basis of planning for prospective increases in traffic. Practically every community can be benefited by improved transportation service, so that the problem of planning these facilities is a problem of improving them.

SYSTEM COMPLICATED BY FARE PROBLEM

The fare situation complicates the planning of transportation facilities. It is contended by some that the American development of a flat fare, practically regardless of length of ride in urban communities, has been thhe chief cause of electric-railway troubles. With increased expenses and extensions of lines forcing increased fares, the inevitable tendency has been to drive off the profitable short rider and retain the unprofitable long rider. The opponents

of the flat-fare system contend that the zone-fare system, under which the car rider pays in proportion to the length of his ride, will produce sufficient profit from the short rider to reduce the fare of the long rider below the amount which it would be necessary to charge without the profits from the short rider. Several attempts to inaugurate zone-fare systems in this country have been failures, although to a very limited extent there are partial zone-fare systems in existence. No situation is known in the United States comparable to some European systems on which zones of less than one mile in length and unit fares of two cents are established. The difficulties encountered in controlling zone-fare collections which require comparatively elaborate systems of identification checks, have practically prevented a fair trial of this system in America.

A reasonable solution of this fare problem should give a powerful impetus to transportation development. If, as was done in one small city, by simply inaugurating a different fare system, gross earnings may be increased 30 per cent., traffic 50 per cent. and expenses practically nothing, there are possibilities in the development of transportation, and particularly railway facilities, that are hardly suspected at present.

The trouble with our present system is that we have no sale for the product of 50 per cent. of our plant during 14 hours out of 24, and 90 per cent. during six other hours. We are operating above capacity for a few hours each day and the rest of the time we have empty seats in cars on the street; empty cars in the barn; unused power capacity paid for; and unused man power which must be guaranteed a living wage whether used four or eight hours a day. If this unused equipment could be put to work profitably, everyone would be the gainer. When someone, sometime, devises the means for selling this product, or by-product, the resultant reduction in cost of transportation and stimulation of traffic will produce great benefits for urban communities and their transportation systems.

INFLUENCE OF TOPOGRAPHY

Careful consideration must be given to the topography. The influence of topography on a transportation problem is

shown by the developments on Manhattan Island. Hemmed in on a narrow strip of land between two rivers, transportation distances have been lengthened and traffic has been concentrated into a few arteries. Such conditions stimulate the construction of very expensive facilities, through the concentrated demand. In a level city, however, such as Chicago or Cleveland, with comparatively few natural obstructions which restrict development, there are very limited possibilities for the convergence of traffic into a single artery or into a few main arteries. Taken in connection with comparatively broad streets, this dispersion of traffic in different directions has stimulated the building of only moderately costly facilities, and has prevented the development of more expensive types, which might have been justified by more restricted community expansion and other physical conditions, such as narrow, irregular, congested streets.

STREET CONGESTION AND REROUTING

Narrow, irregular, congested streets greatly influence transportation plans. The enormous increase in street traffic, which has exceeded all estimates heretofore made, presents a problem with which it is very difficult to cope. If the rate of increase in congestion for the past few years is maintained, the position of large city mass transportation facilities in congested streets will, in a short time, be difficult, to say the least.

The suggestion has been made that street-cars from different sections of the district be routed through and beyond the central congested area, instead of being looped back therein. This would undoubtedly lessen congestion somewhat but, from present indications, the relief would be for a short time only and would involve wastes in service not justified by the temporary advantages. The time is rapidly approaching when all surface-car routes from outlying districts cannot be operated into and through the congested district. The present remedies appear to be:

1. Turning back routes at the edge of the congested district and furnishing transportation through it by short connecting lines more regularly spaced and more efficiently loaded than different through routes can be.

2. The provision of separate grade terminal facilities for street-cars, which will take them out of the congestion. This type of facility is very expensive, in view of the limited general relief afforded, but has been adopted in Philadelphia and Boston with good results.

UNIFIED POLITICAL CONTROL ESSENTIAL

Political subdivisions within districts otherwise capable of unification in community interests have had their influence. This is shown in the New York City situation where, partly on account of the existence of the New Jersey state line, comparatively little development has taken place to the west of Manhattan. The location of Manhattan, with reference to the passenger and freight traffic moving into greater New York from the west and south, forces that traffic into, through or around Manhattan Island to the large industrial, commercial and residential developments to the east and north. The railroads to the south and west would have a considerably greater capacity to serve the New York metropolitan district if the population were more evenly distributed to the west. Internal arteries of traffic would also be relieved by a more even distribution of population. This situation forcibly suggests the necessity for a central political authority acting for all of the political subdivisions of any district in transportation matters. The Port Authority Commission in greater New York, which represents both New York and New Jersey in the development of the Port of New York, indicates the possibility of unifying the political control over the general development of facilities vital to the life of districts split up by even so important a boundary as a state line.

STEAM RAILROADS

Steam railroad transportation has played a large part in the development of residential areas supporting industries. Naturally, however, the predominant influences in the location of railroads have been favorable grades and service for industrial locations. Industrial sites generally are at low levels along rivers and it naturally follows that the leading characteristic of railroad service

is connection of industrial centers. The connection of these centers with residential areas has been largely incidental to railroad development.

Prior to the general extension of electric-railway facilities, railroads were the largest, almost the only, means for the development of residential areas remote from industry. These residential sections in almost every large city are a most vital support to the industries of the cities, but generally have approximated the limit of their development under present conditions.

The local mass transportation service performed by steam railroads has become more or less a by-product of the heavy freight and through passenger service, which is their chief function. When railroads are prosperous and congested, this local passenger traffic is generally burdensome and unprofitable, reducing the capacity of the railroad for more profitable traffic. When, however, business is depressed, and through traffic is light, this local mass traffic shows good returns. One essential for adequate mass transportation service is regular close headway during the middle of the day and between seven o'clock and midnight. On account of the comparative scarcity of local traffic during these periods, this service cannot be performed by railroads generally at a profit. In addition to lack of traffic, the presence of the necessary service at the times required would reduce the capacity for more profitable heavy through service.

The one reason why steam railroads function as well as they do in local service is that their investment has been made principally for the purpose of providing heavy through service, and this reduces the investment charges against the incidental local service, the operating costs of which, where capacity is adequate, are at a minimum. The relative operating costs of steam railroad and surface electric railway service are indicated by a comparison of trainmen's time for a railroad train of 10 cars, seating 700 passengers, and seven street-car trains of two cars each, seating the same number, between two points, 15 minutes apart by train and 30 minutes apart by street railway. The railroad service requires an equivalent of two man-hours (that is, a crew of eight for 15 minutes). The street railway requires 10.5 man hours (that is, 21 men for 30 minutes).

There are sections of steam railroad lines which, if relieved of other traffic, might be comparatively inexpensively adapted to mass transportation service without unduly diminishing the value of the railroads to the community. Careful consideration should be given each situation. Plans for the use of such sections should be dominated by the idea of co-ordinating their service with local mass transportation facilities and not by the idea of selling a by-product of the steam railroad system.

Summing up the general railroad situation in local mass transportation:

Railroads are generally located in industrial and commercial centers. Local passenger service restricts and reduces other railroad service—service which is more valuable to the community as well as more profitable to the railroads. Mass transportation service generally can better be performed by adequate electric railway facilities connecting industrial with residential districts, where volume of traffic and other conditions are such as to justify the large investment therefor. Such sections of railroad as may properly be utilized as parts of local mass transportation facilities should be included in the plans.

TYPES OF FACILITY

After the various factors—present and prospective characteristics of traffic, topography, fares and political relations—have been estimated, plans may be made to apply that type of transportation facility best adapted to each one of the different traffic problems encountered. In a simple problem involving a small community, one type may suffice. In large communities, there are included in the general problem a number of different transportation needs which may require different types of facility for the best general solution.

The different types of transportation facilities to be considered are:

Trackless Vehicles. These include, gasoline buses and trolley buses.

Electric Railways. These include surface street railways, elevated railways for surface cars, subways for surface cars; rapid transit elevated roads and rapid transit subway.

Railroads. These include railroads engaged primarily in through freight and passenger transportation service.

Special Types. Among these may be mentioned, inclines, cable-cars, and moving platforms.

The relative positions of the bus, surface car, elevated and subway are indicated by the following ratios found by Mr. H. M. Brinckerhoff, a recognized authority on urban transortation:

	Capacity	Speed	Invest-ment	Operating cost per car mile
Bus	1	1	1	2
Surface car	1.7	1	2	1.8
Elevated	6	2	12	1.2
Subway	7	2	36	1

From these figures may be derived the relations of operating costs per passenger mile, *assuming a full capacity load for all types*:

Bus	14
Surface car	7.41
Elevated	1.4
Subway	1

It must be remembered that such statements are very general in their nature and cannot be applied indiscriminately to all situations.

The trackless vehicles have less capacity than street railways, cost more to operate per vehicle mile and require less investment per route mile. The trackless trolley, which requires an overhead electric power distribution system, involves a greater investment per route mile than the gasoline bus, but its operating cost is less. Its capacity is equal to that of the gasoline bus.

The street railway, requiring both power system and track, involves a greater investment per route mile than the trackless trolley, but its operating cost is less and capacity greater.

Elevated and subway terminals for street railway cars reduce operating costs and increase capacity somewhat, but greatly increase investment costs.

The rapid-transit elevated obviously requires much larger investment expenditures. Its operating costs are much less than street railways and its capacity is much greater.

The rapid-transit subway requires a still greater investment than the elevated. The operating expenses are somewhat less. and the capacity slightly greater, than in the case of the elevated.

Railroads engaged primarily in through passenger and freight service must be considered in this problem, but the healthy expansion of their urban passenger service appears most difficult.

Special types of facility, such as inclines, cable-cars, moving platforms, etc., may be adapted to unusual conditions of topography.

The use of an incline to open up the development of an otherwise inaccessible area, by connecting that area directly with street railway or rapid-transit facilities, may be justified in special cases. The disadvantage is inconvenience of bodily transfer between the incline and other types of service. This bodily transfer has been avoided in some instances by operating street-cars over inclines as a part of their route. This method, however, adds a large expense and sharply restricts the capacity of the route affected. Fifteen cars an hour in each direction is about the limit; and, unless an unusually large incline is provided, the cars must be small and operate in single units.

Cable-cars are rarely used to-day and are limited to grade conditions beyond the ability of electric cars to negotiate safely.

Sub-surface moving platforms have been seriously suggested for Forty-Second Street cross-town traffic in New York, for the purpose of relieving the streets of pedestrian traffic and providing a convenient by-pass for traffic between rapid transit and other transportation facilities.

Volume of traffic, length of haul, fares, and grade conditions all have a large influence upon the type of facility best adapted to any particular demand for transportation.

THE BUS

The trackless vehicle, requiring less capital outlay than the railway, can be supported by a smaller number of passengers.

Its limited capacity, however, restricts its use in the heavy rush-hour traffic of cities. In addition, the flat-fare system generally in use in America restricts its use for long-haul traffic at the usual rate of fare. The increased operating costs per vehicle mile, as compared with rail facilities, wipes out the margin between fares and costs when the average length of ride approaches the average of street railways, at the railway rate of fare. The advantage of investment charges lower than for railways is overcome before the length of haul approaches that of street railways. Abroad, the zone-fare system, which adjusts fares to length of ride, maintains the advantage of low investment charges.

As opposed to this idea, the Fifth Avenue (New York) bus system is often cited as an example of successful bus operation. These buses, however, operate along a densely traveled thoroughfare, a show place for the country, in a city which enjoys the greatest number of visitors of any American city, and where people go to spend money. The total cost per passenger carried in 1921 was 8.03 cents. The traffic carried was two per cent. of the total mass traffic of metropolitan New York. The rate of fare is 10 cents as compared with a street railway fare of five cents. This operation, which has recently become very successful and prosperous, is unique and cannot be useful as an example of what can be accomplished by motor buses in other cities under conditions of traffic generally encountered.

The usual field of the trackless vehicle lies in carrying traffic too light to justify the investment necessary for track construction. There are a number of instances, however, in which buses are doing a profitable business by taking away traffic which has been built up and served by the electric railways.

Popular prejudice against street railways and the impulse to board the first vehicle offering service has furnished considerable traffic for buses. This has been reflected in higher street-car fares or inferior street-car service, or both. In some communities a choice between buses and railways, made necessary by unprofitable street-car operation brought about by bus competition, has forced practical elimination of the bus. Des Moines attempted to supplant street-car service by buses. This was done for a time. During that time buses were entirely unsuccessful in

furnishing transportation service comparable to that of the street-cars, and the latter have resumed operation with bus competition practically eliminated.

Special service may be properly supplied by buses over long distances in special situations. On the California highways, there are numbers of apparently profitable bus routes. Several street railways are operating buses into undeveloped suburban districts because of the popular demand for such service. Special service is also being rendered by high-speed limousine buses between cities forty to fifty miles apart, with speed greater than on inter-urban railways and comparable to steam railroad time. One electric railway is operating such service probably on the theory that the short rider between the numerous small intermediate towns on the line is more profitable than the through rider, and that through traffic will be stimulated by faster time and more comfortable service.

The principal field for the bus in urban mass transportation, however, seems for the present to lie in furnishing service for un-developed sections of the community where the traffic is too light to justify railway construction. There is also an opportunity to use the bus to divert traffic from congested centers and shorten hauls by establishing a bus cross connection between two lines outside the congested centers.

The future of the trackless vehicle as a mass transportation agency is more or less vague. The enormous increase in the number of automotive vehicles within the past few years, however, strongly indicates that they may provide service to a greater extent than is at present generally anticipated.

A total of 5289 buses and gasoline cars are now operated in common-carrier passenger service.

In twelve states and the District of Columbia, 357 trackless vehicles are operated by electric railways.

According to *Automotive Industries,* there are over 10,000,000 automotive vehicles in this country.

The importance of the automobile as a factor in the urban mass transportation problem is indicated by the results of a recent survey made in Baltimore. In one day there were movements in and out of the delivery district as follows:

76,234 pleasure automobiles.
37,024 commercial automobiles.
21,036 street cars.
4,224 buses and taxicabs.
13,821 horse-drawn vehicles.

Assuming an average of two passengers for each pleasure automobile, bus and taxicab movement, 365 days in the year, this traffic would amount to about 59,000,000 passengers or 25 per cent. of the street railway traffic of Baltimore in 1921.

If a prediction of these facts had been made five or ten years ago, it would have been generally discredited, to say the least.

To offset the effect of higher operating costs, there are some advantages in the trackless vehicle over street railway service:

1. It is not seriously affected by many blockades which hamper street railway operation. This flexibility frequently permits a higher scheduled speed which, in particular instances, may offset its normally higher operating costs.

2. The bus takes on and lets off passengers at the curb, making the service in this particular more attractive.

3. Stopping at the curb, the bus is out of the line of moving vehicles and does not so greatly interfere with other street traffic as does a street-car when it stops to take on or let off passengers. The gasoline bus is also applicable to special traffic movements, which cannot be served on regular routes.

The principal disadvantage of the trackless vehicle, as compared with the street-car, is its limited capacity. It cannot cope with the rush-hour problem of an ordinary American city.

One hundred and fifty street cars (seventy-five two-car trains) would move 12,000 passengers in one direction in an hour on one street. Two hundred and twenty-five platform men would be required. To move this same number by bus would require, in good weather, about 200 buses of the Fifth Avenue type and 400 men to operate them. The element of cost involved in paying the 175 aditional men for the rush-hour periods only (one of the grave problems of electric railway operation) shows the unsuitability of buses for this kind of service. The other operating costs of the type of bus required would also be greatly in excess of street-car costs, and for the ordinary length of street railway

route on the usual flat rate of fare would more than wipe out profits.

One point regarding the trackless vehicle is the damage to street paving caused by its operation. This cost is now borne by the taxpayer. Street railways, in the past, have been compelled to pay for large amounts of paving not damaged or used up by their service. The bus may, in the future, face the problem of paying for the unusually large depreciation of paving due to its operation.

RAILWAY SERVICE BASIC

There seems to be little room for doubt that electric railways, either street or rapid transit, must form the trunk of any system of mass transportation for cities of any size, and it is becoming increasingly evident that they must be largely used to serve mass traffic, if the advantage of service cheap enough to stimulate community development is to be retained.

The field of the street railway lies between the bus and rapid transit; offering the most economical and attractive service for traffic too light to support expensive rapid transit facilities and too heavy, or too expensive on account of length of haul (or both), for the bus.

The maximum labor demand for street railway operations in city rush-hour periods is materially below that of the bus, and is one of the largest elements in preventing the bus from being a real competitor of the street railway in the larger cities. Rapid transit has a similar advantage over the sreet railway in low labor demand, but the investment required for rapid transit is relatively much greater as compared with the street railway than the investment for the street railway as compared with the bus.

Street railways generally suffer from an adverse public opinion which is inflamed by annoyances arising from disadvantages inherent in surface street railway operation. Adverse public opinion has, in the past, operated to prevent the proper adjustment of fares to the cost of service, and also other adjustments in facilities and service which would have benefited both the railways and the communities served. This feeling has had

a great deal to do with the popular approval of the bus as a competitor of the street-car, and is a factor to be recognized in plans for mass transportation. One of the causes for this hostility has been the interference with street-car operations by other street traffic, bringing about irregularity and vexatious delays. The effect of this interference is aggravated by the inflexible routing which must be followed practically regardless of obstacles. All cars operating over one track are necessarily delayed by a blockade on that track.

Except where safety zones are established, the stoppage of a street-car to take on or let off passengers stops all vehicular traffic in the direction of the car. This aggravates congestion. It is apparent to the users of other vehicles that traffic would be greatly expedited by the elimination of, or a reduction in the number of, street-cars on congested streets; and the feeling undoubtedly exists that by better routing or by separate grade facilities, the street railways could relieve a condition which threatens at least partial paralysis of some important traffic arteries. There is no present complete substitute, however, for the surface street car. Expensive separate grade facilities, which cannot be supported by the street-car rider alone, offer the most effective means for relief. Withdrawing cars from congested streets and routing them over less crowded ones offers a remedy in situations where this amount of relief will meet the requirements. Such rerouting usually involves a withdrawal of the service rendered by long lines, to the edge of the congested district. This creates public hostility and should not be resorted to unless it is offset by a general improvement of the service through more rapid and regular operations. In any rerouting plan, service withdrawn should, if the demand justifies, be replaced to the limits of street capacity by short-routed cars connecting with the re-routed long lines by transfer. Delays to short-line cars in congested streets will not have such a generally demoralizing effect on service as will delays of the same duration to a number of long routes.

To repeat, expensive, separate grade facilities offer the most effective means for relief from street congestion.

SEPARATE GRADE TERMINALS FOR SURFACE CARS

In studying the question of separate grade facilities for surface street cars, due consideration must be given to the conditions which, in many cities are rapidly depreciating the value of the service rendered by street railways forced to operate through congested areas on the street surface. Delays to car operation are greatly increasing the cost and decreasing the quality of the service. Increased cost increases fares and tends to drive away passengers. Those remaining must bear a larger part of the cost of service. Depreciated service, also, drives away passengers and increases fares. This product of increasing congestion—increased costs, increased fares, decreased traffic, back to increased costs—certainly presents a striking example of a vicious circle. In order to preserve the indispensable electric railway as a useful facility it may be necessary for the general community to furnish adequate terminal facilities and distribute the burden of cost as nearly as possible in accordance with the benefits derived. The car rider should pay for whatever benefit he derives in the way of decreased costs and improved service. In any event, separate grade terminal facilities for street railways should be given careful consideration in any general plans for large city mass transportation facilities.

It should be borne in mind that there are two types of service performed by separate grade facilities. One, which is simply a terminal for street-cars in the congested district, takes them off the streets, thereby improving the quality and economy of operation of the service affected. The other type, generally adapted only to long-haul traffic, provides large-capacity, high-speed electric railway service.

Of these two types, the one which simply provides for separate grade terminals for surface street-cars, requires less investment cost, because of its shorter length and less elaborate equipment and station facilities. Rarely, however, can surface car terminal facilities be justified by the economy in operation, stimulation to traffic, or in the benefit to the car rider for which he is willing to pay. The only way in which the large expenditure necessary for their construction in the most expensive location

in the community can be justified, is by the general benefit to the community from the reduction in congestion in the central business area and from the speeding up and improvement of transportation service and traffic generally. The speeding up and improvement of transportation produces a real benefit to the population and business institutions affected, inasmuch as it increases the proportion of the whole population from which support for central business activities may be drawn, and makes the service itself more attractive.

Generally, the volume of traffic which can be accommodated in surface street-cars operating in separate grade facilities is not sufficiently great to justify the addition of the interest charges to the fare· particularly if a terminal extending considerably beyond the central congested area were required to avoid congestion. The investment cost of elevated railways is one-third that of subways, and they provide almost the same amount of relief.

In this connection, consideration must be given the fact that a rapid transit system would have six times the capacity for traffic that a separate grade street-car terminal would have. If a volume of traffic can be attracted from the street-cars, sufficient to load a rapid transit system to capacity, the principal requisite for that type of facility is supplied, and strongly indicates that the large capacity facility is better adapted to the traffic than the separate grade surface car terminal.

RAPID TRANSIT

The most effective type of mass transportation facility for consideration is the separate-grade electric railway called rapid transit, on which large capacity cars are operated at high speed. Its principal advantages are large capacity, high speed and low operating cost. Its disadvantage is high investment cost. This disadvantage is not so great in the case of the elevated railway as in the case of the subway, while the advantages of large capacity and high speed are not so greatly in favor of the elevated as of the subway. Express tracks and loading facilities for elevated railways are not so readily provided as in the case of subways.

Public antipathy to elevated railways should not prevent the

construction of such facilities where justified, if financial considerations prevent subway construction. The general advantages from better and more nearly adequate transportation service which can be rendered by elevated railways, offset their defects. Philadelphia has recently completed an up-to-date, elevated, rapid-transit line between Philadelphia and Frankford. The enormous benefits to be derived from such a facility would seem to counteract all its disadvantages.

A large volume of traffic considerably in excess of the utmost capacity of all of the other types of facilities available, is the prime requisite for a rapid-transit system. Interest charges upon the large investment necessary must be spread over a large number of individuals deriving benefits from the system. Passengers on rapid-transit cars are not the only beneficiaries, but, unless they are numerous, there will not be enough of general benefit to justify the necessary heavy expenditure.

Rapid-transit systems generally may be expected to double the speed of service. This means a large increase in the distance and territory within which the population of the district served may support its industries and institutions. If the rapid transit serves under-developed territory in a growing district, it will stimulate the development of that territory for the use to which it is best adapted.

As stated above, in those communities in which development is practically unobstructed by topographic conditions, such as rivers, hills, ravines, etc., the dispersion of population in all directions from the central business area prevents concentration of enough traffic in a single artery to justify expensive rapid-transit systems. Chicago is an example. In such communities, not only is the demand for transportation distributed over a large number of arteries, but the comparatively short distances and correspondingly short time between traffic centers reduces the general demand for faster transportation.

On the other hand, in some communities the development of industrial, commercial and residential areas, together with the number of connecting highways, has been restricted by topographic conditions. Development has naturally taken place in the restricted areas best adapted, at favorable points along the limited

number of highways. Congestion in these highways has brought a heavy demand for passenger transportation service to relieve them and permit the orderly adjustment of housing, industrial and commercial developments in areas best suited for their respective purposes. This demand for transportation, concentrated in a few highways leading in the same general direction, has resulted in a heavy volume of traffic justifying the construction of expensive facilities. The distances between neighboring traffic centers, increased by the restrictions of development, has undoubtedly augmented the general demand for transportation. In this way, by providing a concentrated demand for passenger transportation capable of being supplied by a single artery, topographic conditions work to the advantage of expensive rapid-transit systems. The more congested the few highways become, the more insistent becomes the demand for relief which in large quantities can be afforded only by a rapid-transit facility of large capacity.

If a system could be designed to connect adequate areas, developed and suitable for development for industrial purposes, with adequate areas developed and suitable for development for housing purposes, there could be no question but that the passenger traffic now moving between those areas would avoid the slow and, in some cases, tortuous movements around natural obstacles and flow through the rapid-transit system.

The diversion of passenger traffic from the more expensive service rendered by facilities other than rapid transit, would effect economies which would partially offset the larger investment necessary.

Relief of the other arteries of traffic would ensue. Adjustment of development, by the release of territory adapted to industrial use through the removal of residents to areas better adapted to housing development, would be stimulated and would in turn create new traffic for the mass transportation facilities.

New York (Manhattan Island) is the most striking example of how traffic is affected by restricted expansion, stimulated by a rapid-transit system. Restricted in all directions except to the north, with distances between traffic centers creating a strong demand for fast transportation facilities and with its few traffic arteries taxed to the limit, the opening of rapid-transit outlets

for this traffic has always brought a rush taxing their great capacity.

Rapid-transit facilities, by themselves, cannot be made as valuable to a community as if co-ordinated with other types of transportation. If buses, street-cars and rapid transit were all competing for the same business, service would be duplicated and all three types would probably operate at a loss. If, however, the buses were used as a feeder to the railways or rapid transit, carrying short-haul traffic too light for railway investment, and turning the long-haul passengers over to the rail facility; and, in the same way, if the street railways were used to carry traffic too heavy for buses and too light for rapid transit, feeding to the rapid transit long-haul traffic, which would be unprofitable for the surface car, duplication of expensive service could be avoided. Unnecessary traffic movements could be avoided by transfers and by-passes over auxiliary facilities short of congested centers. By this co-ordination, the best results for the community in good transportation service at the lowest possible rate could be most nearly accomplished.

DISCUSSION

Mr. J. B. Crane:* The speaker mentioned the subject of fare as a vital part of street railway traffic, and the type of fare used. I understand there is a system in use where they sell a weekly pass. I first heard of it in Youngstown a little over a year ago. Their fare had reached nine cents and they could not raise it any more so they started selling a weekly pass for $1.25. This entitled the holder to ride as many times as he wanted, and it was transferable so that his wife and children could go down town on it the same day. In Fort Wayne this system was started in April of this year. The general manager told me after it had been in use for two months that it brought his property from a losing proposition to the right side of the ledger. Their fare had been seven cents and they sold the passes for $1. I understand the same system is in use in Chicago on the elevated railways. It simplifies the collection feature. The conductor is given a certain number of passes on Monday morning and that night he turns in the money or the passes. It also takes care of the psychology feature. When a man digs down into his pocket for a necessity he gets to thinking the man he gives the money to is a robber. On the street cars he does that two to four times a day and each time he thinks the street railway is a robber. In other forms of business, he pays only once a month or once a week and consequently the matter comes to his attention less frequently.

Mr. T. Fitzgerald: The first instance you mentioned was the one given in my paper, in which the traffic was increased 50 per cent. at a small expense.

Mr. W. F. Sanville:† Is there any chance of some day having an adequate transfer system on the Pittsburgh Railways?

Mr. T. Fitzgerald: That gives me a chance to launch into a thing I have wanted to talk about—the proposed contract between the city and the Philadelphia Company—one feature of

*Engineer, George T. Ladd Co., Pittsburgh.

†President, Specialties Co. of Pittsburgh, Pittsburgh.

which is a local body in the management representing the local public and providing "home rule" as nearly as possible under the laws of the state of Pennsylvania. This local body should go far toward solving such problems. The weekly pass would eliminate the transfer problem. A man with a pass does not have to ask for a transfer and does not need, therefore, to be told that he can not have it.

Mr. J. M. Rice:* In connection with the competitive feature between the railroads and the electric lines, I would like to ask how this is going to affect the Pittsburgh situation. The Pennsylvania Railroad carries a large number of passengers. There is considerable by-passing of freight around the down-town business section by the cut-offs at Brilliant and the Ohio connecting bridges, and there will probably be in the future a greater tendency to route through traffic, both passenger and freight, around the city by electrification of the steam roads to give us a much more effective system for carrying local passengers. Has that been considered fully and does it not put a new face on the question? Could not the Pennsylvania Railroad be made a rapid-transit line at comparatively little expense, and some sort of arrangement be made between the railroad and the street-car company whereby one will supplement the other?

Mr. T. Fitzgerald: That is entirely possible in theory. I do not believe it would be a cheap proposition to arrange the Pennsylvania Railroad facilities for close headway mass transportation service. I do not believe the present Pennsylvania Railroad facilities will ever be free of through operation, which in times of prosperity are much more profitable to the community and to the railroad than local mass traffic could be. In times of prosperity you will find steam railroads want to get away from local traffic. In hard times it is profitable all around. In theory the railroad could function as a part of the mass transportation system splendidly and would answer the problem for a good many years to come. There is this one point, however, that I tried to bring out in the paper. The Pennsylvania Railroad, except for the large East End district, is a service connecting industrial and com-

*Consulting Engineer, Pittsburgh.

mercial locations. The function of connecting generally large residential with large industrial areas can not be performed by the Pennsylvania Railroad in its present location. That should be performed ultimately by a local mass transportation system.

Mr. A. E. Anderson:* I should like to know what the actual results of this weekly pass system are as to the riding habit that is formed, and whether it fills up the cars at the times of the day when they would not be otherwise fully occupied while in operation.

Mr. T. Fitzgerald: To be entirely fair to the present system, it should have been stated that the railways in Youngstown, where the large development took place with the weekly pass, had serious competition with a number of jitneys. The company was very unpopular. When the pass was sold, the jitneys could not sell a similar pass because they were independently operated. The man with a pass would not wait for a jitney. There was a large increase of traffic in the lean hours, and the weekly pass rider carried along with him very frequently a high-fare passenger. The ticket fares fell off, but the cash fares did not fall off in spite of the use of the pass. There was every indication that the pass rider was frequently taking along with him a cash rider.

The pass was introduced at Racine, Wis., two years ago, but the results were not nearly as sensational as they were at Youngstown. Since that time it has been adopted in a number of places, showing fair results generally.

Mr. P. W. Price:† The speaker mentioned the impracticability of collecting fares on a zone-fare basis; also that it has been successful in Europe. If so, why can it not be successfully carried on in this country?

Mr. T. Fitzgerald: It is due to the characteristics of the American. They started out in Camden with a well-thought-out system which increased the fares in certain parts of the city. Cars were completely wrecked by car riders who objected to paying a

*Attorney, Pittsburgh.
†Assistant Engineer, County Engineer's Office, Pittsburgh.

higher fare. Wherever it has been tried, there have been public demonstrations against it, which have prevented a fair trial in this country.

In a zone-fare system there must be an identification check showing where the passenger boarded the car and to what point he is entitled to ride; otherwise the fare collector would have no means of knowing whether or not the proper fare had been collected. The holding of that identification check is made obligatory on the passenger. In England if the passenger hasn't his identification slip properly punched or if he is riding past his destination, he is liable to arrest, and they do arrest him. Americans seem to be unwilling to stand for that kind of thing.

Mr. J. R. Buchanan:* The speaker said that in Youngstown the jitneys could not sell a weekly pass. The jitneys in Youngstown have pooled their interests and they sell a strip ticket (six tickets for 50 cents) which can be used on any jitney. Has that affected the situation?

Mr. T. Fitzgerald: I think not. I was in Youngstown a few weeks ago and the number of jitneys I saw was very limited. The street railway was operating gasoline buses itself. I think jitney competition in Youngstown has been almost eliminated. I do not think the general tickets issued by the jitneys have done anything considerable to re-establish the former jitney traffic.

Mr. J. B. Crane: I spent a year in South America where they had the zone system and one reason why it works better there than here is that they do not have the congestion of traffic that we have. The traffic is more equally spaced. I do not see how you could handle a zone system with the crowds we have here. In Bahia, Brazil, they have the zone system with colored conductors, and a white conductor gets on every once in a while and rings up the number of fares represented by the number of passengers and the conductor has to account for that number of fares.

Mr. Ralph Rainsford:† I commuted a good deal between New Jersey and New York at the time of the riots over fares.

*Local Engineer, General Electric Co., Pittsburgh.
†Chief Engineer, Philadelphia Co., Pittsburgh.

I think a good deal of the trouble was due to the agitation in New York for the five-cent fare. On the lines like the one at Englewood, N. J., when the street-car passes a certain point the conductor collects from every one another fare and it is an eight-cent fare.

One thing I noticed in New Jersey was that the car advertisements besought you to patronize the local industries. You have to pay two eight-cent fares to get to the ferry, five cents to cross the ferry, and five cents to get anywhere in New York, and the car advertisements pointed out the advantage of owning your own home and patronizing the local butcher and baker and grocer. It seems to me such a program gives the only possible hope of putting in a zone system here. By paying a little more fare, people reach suburbs having a superior class of residences, and, by favoring home industries instead of making trips to the city, they develop pride in the locality. This should make them realize the necessity and advantage of increased fares for longer distances.

MR. T. FITZGERALD: The increased fare will apply to the worker who does not work in his residence community.

MR. RALPH RAINSFORD: Yes, but it has certain advantages. If there were zones on the South Side the workers would live in the one-fare zone, the first class mechanic would go out into the second-fare zone, and you would go out into the third zone of better residences to get away from the workers' cottages.

MR. T. FITZGERALD: The answer of the flat-fare advocate is that it tends to a wider radius of activity for the inhabitants of any district. They can get the advantage of selling their services in a wider labor market and the industries can secure their labor in a wider market and the whole community is more welded together by the single-fare system than by the zone-fare system. The zone-fare system tends to localize industries and their employees.

MR. W. E. SCHMERTZ:* Have street-car fares in Pittsburgh risen in the past thirty years in proportion to the cost of living?

*Assistant to Manager, Bureau of Instruction, Jones & Laughlin Steel Co., Pittsburgh.

Mr. T. Fitzgerald: No sir. In addition, there is no large street-railway system that has not increased the amount of service rendered for the fare charged, so I should say that street-car fares have not risen at all.

Mr. A. E. Anderson: The Pittsburgh Railways tried the zone system. We had a five-cent fare to certain parts of the city. After a thorough test, it was given up. Taking the question of the number of people who jump on a car, jammed in shoulder to shoulder, it becomes practically an impossibility to collect tickets to any particular point in a zoning system, as we do on our railroad, which is a zoning system.

Mr. W. M. Austin:* Regarding zone fares, about twenty years ago a modified zone-fare system was in operation in Newark, and nearby towns. When the conductor collected the fares in Newark, if the passenger was intending to leave the car in Newark or East Orange, he collected five cents. If he was going to Montclair or further, he collected a larger amount—six, seven, or eight cents according to the distance beyond East Orange—and gave the passenger a receipt. At the border of East Orange, an inspector boarded the car and took up these receipts. If the passenger had boarded the car in East Orange and was going to Montclair or beyond, the conductor collected five cents in the presence of the inspector and rang up the fare. A similar procedure took place on the return trip.

Mr. Fred. Crabtree:† I want to express my appreciation of the very interesting paper. The breadth and thoroughness of the author's comprehension and presentation of the large and complex group of factors involved compel our admiration. This paper enables us to understand better than we ever did before, why there are so many difficulties connected with local transportation, not only in Pittsburgh, but also in all other large cities in this country.

*Electrical Engineer, Supply Engineering Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

†Professor of Metallurgy, Carnegie Institute of Technology, Pittsburgh.

When traction companies were first organized no one conceived, or could have conceived very well in advance, the immense possibilities of their future growth, their far-reaching effect on urban and suburban life, and the great complexity of the problems that were to be developed; for no one had any conception of the future growth of cities and of the manufacturing industries. So no one was in a position to frame sane laws to take care of this growth. All cities and all transportation companies throughout the United States have suffered from this lack of foresight. All have had financial troubles, as they have had misunderstandings, irritation, and lack of comprehension on the part of the public, just as has been the case in Pittsburgh. Now it is possible to get a comprehensive view, and make a reasonably reliable forecast of possible developments during the next decade or so, as we have learned to-night. We may, therefore, look for a more reasonable attitude on the part of legislatures and public, and sounder judgment and better service on the part of public service corporations.

As the paper was read, it left the impression that there are two big problems which are rather distinct from one another. One is the problem of handling the traffic down town. It would seem to be a logical deduction from what Mr. Fitzgerald said that the problem of handling the traffic in the down-town section is bound to be a very difficult one, involving very expensive reconstruction; and it is perhaps unreasonable to expect the street-car company to stand all this expense. The other problem is that of taking care of the transportation between the industrial districts and the residential districts. This problem is growing more serious every year. Pittsburgh, like every other city, is growing. I have been impressed with the necessity of some forecast, or study, of what is going to be the future growth of this particular city in which we live. We are now suffering from the lack of foresight of the people twenty or thirty or forty years ago. Are we going to make the next generation also suffer because of our lack of care and thought with regard to the future? Mr. Fitzgerald has outlined in a brief way one phase or line of such study, and has shown that it requires the very best brains and engineering skill that can be put on the problem.

MR. A. E. ANDERSON: Have street-car fares risen in proportion to the cost of living in the past four years? Have you any comparison?

MR. T. FITZGERALD: I have no figures, but they have not risen either as fast as the cost of living or as the cost of materials entering into street-car operation, and labor costs.

MR. E. R. JACKSON:* I had hoped that Mr. Fitzgerald would mention the solution that Cincinnati has found in its down-town terminal facilities. They have erected a magnificent office building as a permanent terminal and down in the sub-basement of the building the so-called Kentucky cars, serving the cities of Covington, Belleview and Dayton, on the Kentucky side of the Ohio River, can loop and return to the other side of the River. Before this the congestion was simply terrible in the morning and evening. The green cars serving the Kentucky side of the river mixed in with the Cincinnati cars making a terrible jam. Now that has entirely disappeared; and it would appear that the income from the office building, which is really a great credit to the city, would take care to a great extent of the enormous investment they have made there.

MR. T. FITZGERALD: That situation is very special. The large majority of the cars from the Kentucky side of the river reach the approach to this terminal through comparatively uncongested streets. A very short connecting separate-grade facility from the terminus of one bridge directly into this terminal has been provided. The expense of the arrangement has been low. Topographic conditions have permitted cars from directly across the river to come in at one level, and the cars from Newport to come in at another lower level, and all Kentucky cars have been withdrawn from the central congested area. It is an unusually favorable situation, although a most ingenious arrangement, and has worked out very well.

I do not think the office building feature adds very materially to the proposition except that the terminal being in the building adds quite a value to the building for tenants.

*Engineer, Climax Engineering Co., Clinton, Iowa.

Mr. P. W. Price: There is one point, among a great many that Mr. Fitzgerald touched on, that interested me, and I might state it as I recall it and see if my impression is correct. He stated that the cost of street-car subways was too great to be financed by the street-car company. Now the street-car company operates under a franchise that gives it a right to the use of the streets; and, when the congestion on the streets becomes so great that it is no longer possible to operate cars on those streets economically, the street-car company is not getting what it originally had from the city by the grant of the franchise. In one way of looking at this situation, the city should continue, as far as possible, to provide the facilities they originally provided at the time of the granting of the franchise. If the city does not continue to provide adequate rights of way for conducting transportation on its streets, the operating company cannot, in my judgment, be held entirely to blame for poor or inadequate service. Where it is impossible to widen streets to take care of the traffic, the city might consider in lieu of widening certain streets the placing of street-cars under the surface. In fact, a bond issue to do that in this city has been voted on and approved among other projects by the people. What remains for decision seems to be the best location of such a street-car subway loop, or loops, and also on what basis it may be turned over to the street-car company for operation.

Mr. T. Fitzgerald: That presents a very broad view of the problem and with a clearer understanding of these problems, the public will, in effect, adopt it.

VERTICAL TRANSPORTATION

By H. D. James*

The volume of traffic handled by elevators in our large cities is considerably in excess of the volume handled by our horizontal transportation systems. The possibilities for business in our cities to-day depends more upon an efficient elevator service than upon the traction service. The automobile is proving a valuable auxiliary to the transportation service of our cities but, so far, no substitute has been found for the elevator. As our cities grow and the size of buildings increases the elevator problems become more and more difficult.

An ordinary building served by one or two elevators introduces no problems of system. The elevators are merely operated up and down in response to signals from passengers at the various floors. During portions of the time the elevators are idle and it is seldom that their full capacity is required.

As the size of the building increases, a system must be established for operating the elevators, and one of the operators known as a "starter" is placed on the main floor to determine the time for each elevator to leave this floor. It is his duty to maintain an even spacing between elevators and to avoid congestion as far as his facilities permit. A passenger wishing an elevator to stop at an intermediate floor presses a button which causes a signal light to indicate the first elevator approaching that floor in the desired direction. This much of the system is old and with modifications is in use in most buildings. In department stores elevators are stopped at every floor. No call buttons are used. In large buildings it has been found necessary to give the "starter" some control over the elevators after they leave the main floor. This is accomplished by indicating boards which show the location of the various elevators, and sometimes means of communication with the individual elevators have been provided. This enables the operator to speed up an elevator by having it run by

*Manager Control Division, Engineering Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

certain floors and transfer its calls to the next following elevator. A further development of the dispatching system will consist in giving the "starter" control over the speed of individual elevators. This will better enable him to maintain the spacing between the cars. Another improvement under consideration is means for automatically stopping the elevator at the desired floor. Time is lost by an operator overrunning his floor, either due to poor judgment in operating the elevator or because he does not understand a passenger's wish to stop at a particular floor in time to make the landing without reversing his car.

High buildings require the elevator service to be divided into local and express service. For example, a 20-story building will have one set of elevators serving the first 10 floors. Another set of elevators will serve the upper 10 floors. Both cars stop at a common intermediate floor to transfer passengers who desire to travel between floors in the building. A proper distribution of elevators between passenger and express service materially improves the vertical transportation problem.

Recently the tower type of building has introduced another problem in vertical transportation. If all of the elevators run from the ground floor a considerable portion of the building would have too large a percentage of the floor space occupied by elevators. This will require a change in the existing systems of elevator operation, and several plans have been suggested. The problem more nearly approaches the horizontal traction problem and it may be solved in the same way; that is, a few express elevators may run the entire height of the building making only a few stops, the intermediate floors being served by local elevators.

Commercial buildings such as department stores, given over to the selling of merchandise, present another problem in vertical transportation. The best selling floor is at the street level. Other floors become less desirable in proportion to their distance from the street level because it is difficult to induce a large number of people to travel to the upper floors. This has resulted in the offices, store-rooms, packing departments and sometimes the shipping departments of large stores being located on the top floors. In the down-town sections of the large cities, street space is too valuable to permit the parking of delivery trucks around

the building. The introduction of the automobile truck in place of the horse-drawn vehicle is helping to simplify the problem. The automobile truck can now be carried on an elevator to the top floor of the building very easily and quickly. The incoming goods can be delivered by gravity from the top of the building and the outgoing delivery trucks loaded from one of the top floors.

Automobiles, both pleasure vehicles and trucks, are now frequently stored in high buildings by means of elevator service. Many garages in down-town districts utilize the upper floors for this purpose.

With this general view of the elevator problem let us examine some of the machinery used for operating the elevator car.

Power-operated elevators came into use about the time of our Civil War. They were either driven by a steam-engine or belted to a line shaft, the steam-engine at that time being the universal source of power. Many of the modern elevators, both of the worm and spur-gear type, resemble the old steam-driven machines with the exception that an electric motor has been substituted for the steam-engine.

A little later, hydraulic machines of various designs were developed for operating elevators. In general, they can be divided into two types, one having vertical cylinders and the other having horizontal cylinders. They are all operated on a common principle. The hoisting rope passes around two sets of sheaves, one set is anchored and is known as the stationary sheaves, the other set of sheaves is moved by the hydraulic cylinder to different distances from the stationary sheaves. The movement of these sheaves causes the car to ascend or descend. The horizontal machines were geared 6:1, 8:1, 10:1 and 12:1. In some types the sheaves were pushed apart by the hydraulic machine and in other cases they were pulled apart. Vertical machines are usually geared 2:1, 4:1 and 6:1 and are of the pulling type. Some vertical machines were designed for operating at a water pressure of 1000 pounds per square inch and were of the pushing type similar to a hydraulic ram. The use of high pressure permits water to be pumped at a central station and distributed over a considerable area. Systems of this kind were developed to a considerable extent in England. In 1904 the writer presented a

paper before this Society describing various systems of this kind which were then in use and which gave promise of economical development. In Pittsburgh both the Bessemer Building and McCreery's store were operated from power-stations located a considerable distance away. More recently McCreery's store has been changed to electric machines.

The latest development in hydraulic elevator machines is known as the plunger type. This form of elevator was introduced very early for short rises, but for high rises difficulties were experienced in drilling the hole for the plunger. The elevator machine consists of a cylinder and plunger which are sunk in the ground underneath the elevator car. The plunger must be a little longer than the travel of the elevator car. When this type of machine is used for the main elevator in a building, the hole in the ground must be drilled as deep as the building is high. As the car rises, the plunger comes out of the water losing one seventh of its weight. The pressure on the bottom of the plunger also decreases 0.43 of a pound per square inch for each foot of travel. Both these features cause a change in the force available for lifting the car and it is therefore necessary to use a rope counterbalance in order to maintain a constant value for the work done by the hydraulic machine.

About twenty years ago the plunger type of elevator became very popular. The passenger riding in the car had a feeling of security due to the absence of the slight springing effect present in rope-operated machines. Also, the sight of the large plunger supporting the car had a psychological effect. This latter reason for security was superficial on high-rise elevators. The use of counterbalancing ropes placed the elevator plunger in tension after the car had traveled a short distance. If the plunger should break close to where it was fastened to the car the counterbalance would cause the car to ascend very rapidly and result in a wreck. Such an accident has been guarded against by having the bottom of the plunger attached to the car by means of several steel cables located inside the plunger, which is a tube. As far as the writer knows, an accident of this kind has never occurred on a plunger machine.

American ingenuity overcame the difficulty of drilling the large holes necessary for the high-rise elevators of this type and there are a number of installations having a car travel of approximately 300 feet.

The electric elevator which is now the common form was introduced about 1890. For many years the only type used high-speed motors geared to winding drums. Passenger machines were usually provided with worm gearing. Freight machines often used a combination of both kinds of gearing. Rheostatic control was used and the motor operated as a generator with an overhauling load. As the electric motor operates equally well in either direction, it is possible to overbalance the car by a weight equivalent to the average load. If we assume that this overbalancing is equal to one-half of the full car load, the motor will do work in lowering the light loads and raising the heavy loads. The maximum work done by the motor is at no time more than that required to lift or lower one-half the full load, which enables a much smaller motor to be used than would be required without overbalancing.

It was early realized that the electric motor consumed power in proportion to the load, and where central power-stations were used there was no expense when the motor was idle. The hydraulic machine consumes the same amount of power regardless of its load because the water is pumped at a fixed pressure and the same volume of water is used for the trip regardless of the load in the car. The hydraulic system required a pumping station in the building which had certain stand-by losses even when the elevator car was not in operation. The inherent economy of the electric machine over the hydraulic has been the one important factor that has caused the electric machine to supersede the hydraulic. Another factor has been the decrease in maintenance cost for the electric elevator. In the earlier stages of the electric machine the apparatus was not very substantial as the art was young and experience was lacking, and therefore the maintenance cost and the indirect cost due to delays made such an elevator equipment expensive to maintain. The cost of maintaining the hydraulic machine has not changed much since the early installations as the hydraulic art is an old one and the engineering prob-

lems were well understood many years ago. On the other hand, the electric drive is new and we are still making rapid strides in improving the engineering features of the apparatus.

It was the ambition of the electrical engineer to make a machine that would operate as smoothly as the hydraulic. Many times I have heard an electric machine described as being almost as good as the hydraulic elevator. The electrical engineer has at last triumphed, and I do not know of any hydraulic machine that compares in smoothness with the latest type of the electric machines operated by the variable-voltage system.

The problem of smooth operation is one of acceleration and deceleration. Persons riding on an elevator car are not usually affected by the speed of operation but they are very sensitive to the rate of change of speed. By taking the second derivative of the speed-time curve, the theoretical maximum rate of acceleration or retardation can be plotted. The ordinary rheostatic method of control used by elevator engineers for so many years does not approach this theoretical curve and this is the reason why the electrical engineer was unable to obtain the smoothness of operation much desired. The hydraulic machine does not conform to this curve but it does not have abrupt changes in speed similar to those caused by short-circuiting sections of the starting resistance in the electric-motor circuit. Hydraulic machines can be adjusted to give a smooth start and stop, but under these conditions they do not accelerate the car as quickly as indicated by the theoretical curve.

Recent studies in systems of control for electric motors indicated that a cushion effect was required in the armature circuit of the motor in order to give the desired smoothness of control. This cushion effect was first obtained with rheostatic control by the use of a reactance coil. This coil together with other improvements gave very favorable results and at once established the electric elevator as a direct competitor of the hydraulic machine.

Good results were previously obtained by the use of a large number of contactors for accelerating and decelerating the motor. These contactors require careful adjustment which is affected by dirt, variations in weather conditions, and other agencies, so that

continual attention is necessary in order to maintain smooth operation. An experienced elevator man could go from one building to another using identical equipment and judge the ability of the electrician in charge of the elevators by their smoothness of operation. When the impedance coil was introduced it was found that the improvement in control resulting from this invention made the operation inherently smooth and that little difficulty was experienced from the control getting out of adjustment.

Another step forward in elevator control systems was made when a relatively old system of control was improved for elevator use. This system is known as the variable-voltage system of control. It consists of an individual generator for each elevator motor. The elevator motor is controlled by changing the value and direction of voltage of the generator by adjusting its field strength. Elevators were operated from a system of this kind twenty-five years ago but the engineers at that time did not understand how to proportion the characteristics of their motors and generators to get the best results and overcome cerain inherent difficulties. With our present knowledge of design, machines can be built which have definite time characteristics so that the rate at which the car speed is changed can be controlled by the design of the machine, and requires very little adjustment in the control itself.

Another remarkable feature in this system of control is the close resemblance between the characteristic curve of properly designed machines and the theoretical curve indicating the maximum desirable rate for accelerating the car. The result has been that elevators operating from this system of control accelerate and decelerate faster than any other type and thus time is saved in handling passengers between the floors of the building. This saving in time is of most importance where frequent stops are made. Perhaps the most important saving is with elevators used in a department store.

The ability of an operator to make an accurate landing at the floor level is of great importance with busy elevators. Time lost in inching a car up and down in order to make a landing often represents a large percentage of the total operating time. The elevator operator must rely on his judgment in slowing down

the car in order to make an accurate stop. This judgment is seriously affected if the car decelerates at different rates with different loads. The operator judges the rate of deceleration by the location of his control handle. If a given location of this handle results in a wide variation in the rate of stopping and speed at which the stop is made, the problem of landing becomes quite difficult. It is well known that the speed of the hydraulic machine varies with the load and this is also true of many electric elevators. Design engineers express it by saying that the regulation of the motor is poor. This regulation can be corrected to some extent by compounding the field of the motor but when several elevator motors are operated from a common generator it is impossible to adjust the generator to improve the motor regulation under the differing conditions which obtain at any one time.

When each elevator motor is supplied by its own generator both the motor and generator can be designed to give very close speed regulation not only at full speed but at a very low speed used in making a landing. This is another advantage obtained with the variable-voltage system of control. The time consumed in making landings is reduced to a minimum because the operator has a definite speed corresponding to each position of his control handle. This speed is practically independent of the load in the car and the operator then learns to judge his stops and can make them with very little loss of time.

When an electric elevator is descending with full load in the car the usual system of control permits a rate of acceleration which closely approaches a free fall, the only retarding force being friction and the inertia of the rotating parts. When the motor exceeds full speed its counter electromotive force increases above the line voltage and causes a current to flow from the motor to the line, resulting in a generator action. This generator action increases very rapidly with a small change in motor speed so that the first effect on the passengers is the sensation of falling, followed by a rather rapid change of speed when the motor torque balances the load. Anyone riding on a high-speed electric elevator will notice this effect after his attention has been called to it. The operation can be materially improved by the proper adjustment of resistors in shunt to the motor armature but eleva-

tors operating from a single-voltage source of supply usually have this effect to a greater or less extent. The hydraulic elevator also has a similar effect although not quite so marked. The descending load on a hydraulic machine causes the water to travel from the cylinder into the discharge tank. The resistance to the flow of this water is in proportion to the square of its velocity therefore the resisting effect under full load is very little at first and increases very rapidly as it approaches the balancing speed.

Electric elevators using the variable-voltage system of control have the elevator motor connected directly to its own generator. The rate of acceleration is therefore controlled by the change in voltage of the generator. This results in the elevator motor generating power at all speeds from the start until the car is operating at its highest speed. This causes the passengers to feel a very definite pressure underneath their feet during the downward motion of the car even when fully loaded, and results in a feeling of security. The passenger has the sensation that he is not having a free fall but that his rate of travel is definitely under control. This sensation can best be illustrated by riding in typical elevators using different systems of control.

In loading and unloading trucks from elevators there is a tendency for the platform to recede from the landing when the truck is moved on the car. It is therefore often necessary to provide positive means for maintaining the car platform level with the landing. At first this was done by means of locking bars operated by a lever inside the car. This is a very effective means for accomplishing this result but also a very inconvenient method. A number of years ago improvements in hoisting machines were made, consisting of a secondary set of gearing which gave the car a very slow motion and by means of a switch located on the top of the car this control was automatically operated to maintain the car platform on a level with the landing. At that time it was necessary to use auxiliary gearing for this purpose as the regulation of the main hoisting motor at low speed was not satisfactory for this purpose.

When the variable-voltage system of control was thoroughly worked out it was found practicable to use the main hoisting

motor for automatic leveling and thus avoid the use of the auxiliary gearing driven by a small motor.

Automatic leveling has been applied to a number of passenger installations. On account of the inherent poor speed regulation obtained with rheostatic controllers, time is lost in making an accurate landing, and the use of automatic leveling for passenger service seemed to be a step in the right direction. This may prove to be the case for certain types of passenger service where rheostatic control is used, but the improved operation obtained with the variable-voltage system of control may make it unnecessary. Such devices, however, are desirable for heavy freight service as they perform the double function of first bringing the car platform level with the landing and then maintaining the platform level during the loading process.

Alternating-current systems of power distribution are rapidly replacing the direct-current systems. This brings us face to face with the question of alternating-current drive for elevators. The induction motor has proved very satisfactory for low-speed passenger and freight service and has been used to a limited extent for high-speed service, but it possesses certain inherent characteristics which render it difficult to apply it to high-speed service. It also takes a large amount of power during the accelerating period. Considerable improvement has been made in the smooth operation of elevators driven by alternating-current motors, by designing the motor to have certain special characteristics and also by the combined use of resistance and impedance in the control circuit; but, at best, the problem is still very difficult and few engineers would recommend such an installation for a high-class office building or hotel.

If direct current cannot be obtained for this high-grade elevator service it is necessary to install a motor-generator set or a rotary to convert the alternating-current power to direct current for elevator service. The best system to use is to provide a separate generator for each motor and use the variable-voltage system of control previously described. This enables the alternating-current power to be used direct to drive the individual motor-generator sets. It also enables the use of synchronous driving motors where power-factor correction is desirable. Automatic

means can be provided for starting and stopping individual motor generator sets so that the stand-by losses may be eliminated when an elevator is not in use. If a single motor-generator set is used for a bank of elevators it is necessary to keep it running during the inactive periods of the day and night which increases the total cost of operation.

Pittsburgh has some very excellent examples of progress in elevator development. One of the most important has been carried out under the direction of a member of our Society and one of our former directors, Mr. Fred. C. Schatz.

As the older residents of Pittsburgh will remember, the Joseph Horne store has been built in sections. As each section was constructed, the best existing type of elevator equipment was installed. The oldest existing section was constructed in 1894 and it had geared vertical hydraulic machines. The next section represents the first passenger elevator installation of the plunger type in Pittsburgh. It was put in operation in 1903. The latest addition to this store has just been completed and the elevators are operated by electric power using the variable-voltage system of control. The power supply is alternating current and the hoisting motors direct current. The power is transformed by the individual motor-generator sets which form part of the variable-voltage system of control.

Automatic floor leveling has been added to one elevator to determine from actual experience if this added refinement is of real value in operating the elevators. Anyone interested in observing the difference between these three well-known types of elevators can obtain a very good idea by visiting the Horne store and riding in turn on each different type. I can assure you that these machines are all kept in first-class operating condition and are therefore very representative of the development of the art.

DISCUSSION

Mr. Morris Knowles, *Chairman*:* I feel quite certain that Mr. James will be gratified if you will ask questions or discuss the paper. Mr. James, you spoke about express elevators. Can you tell us about the proportionate area in different types of buildings that has to be devoted to that purpose?

Mr. H. D. James: I remember an old figure obtained in the down-town district of New York, when I was with the Otis Elevator Company, of about thirty-five square feet for every 25,000 square feet of floor area. That is approximately correct for certain cases, but in selecting the number of elevators in a building it is necessary to know the kind of tenants in that building and the business they conduct. There is quite a difference of opinion on this question, and a good deal depends on the size of the elevator. An elevator should not be more than six feet deep, back from the door, as it takes too long to get people in and out. If a big car is required, make it wide, and open up the whole front.

Mr. W. F. Sanville:† Does the cost of running elevators in high buildings, say over 10 stories, increase in the same proportion as in a lower building, or does the running cost increase per foot as the shaft is lengthened?

Mr. H. D. James: The service depends on the number of miles the elevator travels, and the number of stops per mile.

Mr. W. C. Buell, Jr.:‡ I understood you to say that 300 feet is the limit for the plunger type. Is that correct? It is my impression that the elevators in the Singer Building are of the plunger type.

Mr. H. D. James: I think the Singer Building has electric elevators. I said 300 feet for plunger machines because I had in

*President, Morris Knowles, Inc., Pittsburgh.
†President, Specialties Co. of Pittsburgh, Pittsburgh.
‡President, Buell, Scheib, Muller, Inc., Pittsburgh.

mind the Bellevue-Stratford in Philadelphia which I think is about this rise. When you drill a hole 300 feet deep and meet different strata of rock you are probably glad it was not any deeper.

Mr. W. A. Weldin:* I think Mr. James said it was the duty of the dispatcher to keep the cars equally spaced. The result is that, in buildings having few elevators, one car spends a large part of its time waiting at the top or bottom for the next to come. In the meantime, passengers are waiting at intermediate floors. I have often wondered why that theory of dispatching was adopted instead of keeping the cars going.

Mr. H. D. James: It is not the intention to keep the cars idle. We think of the same thing when we see trolley cars stop at the end of the line and wait while the conductor and motorman eat supper. The idea is to keep the cars busy and not have a lay-over. It is pretty hard to dispatch two cars without lay-over. With four cars it is a little better. You do not have much of a problem when you have less than four cars.

Mr. W. A. Weldin: I have in mind a case where there are six cars. From a casual observation it seems to me that there is considerable loss there due to an effort to keep the cars evenly spaced. The effort seems to be to keep one car constantly idle at the top and bottom, waiting for the next to arrive. This seems to result in about one quarter of the total capacity being idle at all times. As a matter of fact, in rush hours, this schedule is largely ignored. I wonder if the elevator people have ever studied out the best operating schedule for particular conditions.

Mr. E. O. Mueller:† Is there any particular rule for placing the necessary machinery either in the basement or on the top floor or at an intermediate point?

Mr. H. D. James: The best place is directly overhead, to minimize the bending of the rope. Very frequently we have to use a deflector sheave for the counterweight. While that is the

*Blum, Weldin & Co., Pittsburgh.
†Secretary, Buell, Scheib, Mueller, Inc., Pittsburgh.

best arrangement, machines are sometimes placed in the basement or on an intermediate floor.

MR. A. G. McGARVEY:* The reason for having a dispatcher for elevators is to give service. It may seem sometimes that you have to wait quite a while, but it is not the dispatcher's fault. Some men are able to operate an elevator more quickly and efficiently than others. They can make two trips while others are making one. The dispatcher keeps all of the cars going and each man doing his share. If a man cannot keep up, the dispatcher replaces him with one who can. Thus all cars are kept moving quickly and efficiently.

The saving effected by making correct stops is shown by the following tests. The elevator tested is an Otis, one to one, traction type for passenger service, equipped with a 34-horse-power, 135-ampere, 220-volt, Otis traction motor. The elevator travel is 240 feet, serving 21 floors.

Test		Watts	Complete trip minutes
1.	Empty car running *down* making no stops	165	
	Empty car running *up* making no stops	11	1
2.	Empty car running *down* making all stops	460	
	Empty car running *up* making all stops	380	5
3.	Empty car running *down* stopping before reaching floor and having to go about a foot farther to reach floor level	620	
	Empty car running *up* stopping before reaching floor and having to go about a foot farther to reach floor level	526	6
4.	Empty car running *down* stopping past each floor and having to come back about a foot to reach floor level	606	
	Empty car running *up* stopping past each floor and having to come back about a foot to reach floor level	780	6

*Chief Engineer, William Penn Hotel, Pittsburgh.

This time does not include the opening and closing of doors or the loading and unloading of passengers. It is not often that all stops have to be made. One trip every 10 minutes would be a fair average for an 18-hour day. This means that each elevator would make 108 trips.

If the landing is not reached and it is necessary to go farther to reach the floor level, the additional current per day of 18 hours per car would be 33 kilowatts.

If the landing is passed and it is necessary to come back to it, the additional current per day of 18 hours per car would be 59 kilowatts.

Mr. H. D. James: I do not understand the schedule of 10 minutes.

Mr. A. G. McGarvey: The 10-minute trip would be in case they made every stop and made them incorrectly. It was assumed, in order to approximate the number of trips per day. During some parts of a day, cars make fewer trips. Most elevators make a trip in less than 10 minutes. As shown in the tests, a complete trip can be made in one minute. The assumption was made in order to show how much current could actually be saved by correct stopping of the car at the floor level.

Mr. G. E. Flanagan:* Mr. James notes a marked improvement in the construction of elevators. I would like to ask if he or any of the elevator men present have found any way to improve the people who use the elevators. Pittsburgh people do not like to take second place to those in New York or elsewhere, but I think it is noticeable that people in New York get in and out of street-cars in just about half the time they take in Pittsburgh. It seems to be due to human inertia that when the car stops they are very slow to leave it and make room for people coming in—that is very noticeable. People will leave elevators in an office building in considerably less time than they do in department stores. Is it possible to educate us to make better use of this machinery than we do at present?

*Mechanical Engineer, Heyl & Patterson, Inc., Pittsburgh.

Mr. H. D. James: That is a problem in itself. The shape of the car and the size of the opening provided have a great deal to do with it. And you cannot expect customers in department stores to move as rapidly as people who are carrying orders for stock brokers. There is quite a difference in human temperament, and that is part of the problem of the man who designs the elevator lay-out.

Mr. Morris Knowles, *Chairman*: The implied corollary of Mr. Flanagan's remarks in the other direction is how we as a public change our minds toward transportation. Some years ago it was not a serious matter if one lost a stage coach; he could take another stage the next day. Then steam-railroad transportation came in, and there was considerable change when the express trains ran, and people missing them expressed displeasure when obliged to wait a few hours for another. Street-car transportation has aggravated the situation somewhat, so that when people are left on a street corner, even when there is another car in sight, they are very apt to complain. And now, in a building with express elevators, if the door be closed in your face and the car starts up, you are very much disturbed and dislike to wait for the next car already opening its door to receive you.

Mr. H. D. James: We made an interesting experiment in Chicago on an elevator operating at about 500 feet a minute. The car was reversed from full speed in one direction to full speed in the other direction in three seconds. In such a case, there is no unpleasant sensation if it is done just a few times; but, if you keep it up for several minutes, it will be disagreeable. Most elevators do not exceed 600 feet a minute, but I think we are approaching 1000 feet. We run mine hoists 3000 feet a minute.

Mr. W. A. Weldin: Perhaps this difference might be explained by the fact that machines designed to hoist ore at high speed are slowed down when men are about to ride.

Mr. M. W. Von Bernewitz* Those hoists that run 3000 or 4000 feet a minute are cut down to 800 or 1000 feet when men

*Mining and Metallurgical Engineer, Pittsburgh Experiment Station, U. S. Bureau of Mines.

get on. The regulations will not permit more than 800 feet. I would like to ask whether the speaker has any figures on the number of people traveling vertically and horizontally.

MR. H. D. JAMES: Several surveys have been made but I do not have the figures. The number of trips per person is greater, but the car carries a passenger vertically only 100 or 200 feet whereas he may travel several miles horizontally. I referred to the number of trips per person and not to the number of miles traveled.

In regard to the rate of travel I know I have traveled 1000 feet a minute on elevators and I do not think the sensation was at all objectionable. Railroad trains travel 5000 feet a minute and aeroplanes much faster. Some elevators traveling at 800 feet a minute are much more comfortable than others traveling only 400 feet. It is just like traveling 40 miles an hour in a Ford and 60 in a Pierce-Arrow. It is the rate of change of speed which gives you the disagreeable sensation. I see no reason why elevators should not run 1000 feet a minute. It may be against the law but all laws are subject to change. I wonder if Mr. Von Bernewitz has any physical tests that indicate 800 feet a minute as being the maximum speed for vertical travel.

MR. M. W. VON BERNEWITZ: The physiological effect caused by acceleration is the chief objection to high speed.

MR. W. M. AUSTIN:* I would like to have Mr. James tell us something about the function of the air-tight doors that are provided on the elevator shaft on the lower floors of some of our tall buildings. I understand they are for the purpose of slowly stopping the cage in case of accident.

MR. H. D. JAMES: You probably refer to the air cushion which was introduced some twenty-five years ago. There used to be a fellow working for us who had a large number of dents on the top of his head. It was explained that he got those testing air cushions for elevators. The air cushion is a tapering box which

*Electrical Engineer, Supply Engineering Department, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa.

the elevator enters, causing the confined air to act as a buffer. I have never thought much of these air cushions. I should hate to be in a car when it hit the cushion. With a drop of 100 feet, the rate at which you would be traveling would be something over 800 feet a minute and the deceleration would have to be rather abrupt. The air cushion is a patented device which paid a royalty on every one that was put in, and the state of Pennsylvania required them to be installed. Considerable money was spent on elevators in those days.

Mr. M. W. Von Bernewitz: Is the Woolworth Building the only one in New York with air cushions?

Mr. H. D. James: I think not. The Frick Building used to have them, but I think they have been opened up, as the oil buffer is very much better. I would rather take a chance with the oil buffer than with most other safety devices. At a speed of 600 feet a minute the air cushion will not retard you appreciably.

Mr. G. E. Flanagan: Is the hydraulic type superseded by the electric or are both still being manufactured?

Mr. H. D. James: I do not know what new hydraulic installations are being made. They are certainly not all superseded. At East Pittsburgh the Westinghouse Electric & Manufacturing Company has two hydraulic machines, both installed in 1894. The cylinders are half an inch out of round now, but it does not cost much to keep them up, and there is no immediate need to change to electric equipment. Hydraulic machines are being gradually changed as the cylinder wears. When the time comes to buy a new cylinder it is cheaper to buy a new electric machine. I do not know of any contract let in the last two years for high-rise buildings where hydraulic machines were considered, but for short-lift machines—10 to 25 feet—the hydraulic is most economical if you can obtain water pressure without too much expense.

Mr. G. E. Flanagan: I have not heard of any installations of the 300-foot plunger type in recent years.

MR. L. J. SCHWARTZMAN:* In the variable-voltage system you have a set, consisting of an alternating-current motor driving a direct-current generator, and an exciter which is kept running all the time. Is not considerable current consumed in this set when the elevator is standing idle?

MR. H. D. JAMES: Most of the current is the wattless current. I do not recommend having it run all the time when the elevator is not in action. When you discuss the question of economy you have a number of things to consider. If you use constant voltage you are burning up power every time you start and stop. If you use the variable voltage system of control you have the stand-by losses. There are places where the variable-voltage system of control would not be economical. In the one I referred to you have frequent elevator service, such as in office buildings and large hotels and department stores. In those places, particularly the office buildings and department stores the elevators are run continuously on schedule. During inactive parts of the day you can shut down part of the elevators.

MR. H. F. BUCHER:† I would like to ask where the machinery should be placed, overhead or in the basement, keeping in mind the safest operations at all times and in the case of fires.

MR. H. D. JAMES: That depends. I might offer this suggestion. Fire has a tendency to go upward. If you expect your fire to originate in the elevator machine, it would be safer to have it at the top rather than at the bottom. If a fire were started, it would spread faster in the basement than on the roof. In the case of a basement fire you could probably maintain your elevator service longer with the machine overhead than in the basement. But under ordinary fire conditions, operation of elevators is limited by the hot gases going up the elevator shaft and the car may be put out of commission long before the operating machinery is injured. In case of water the damage threatens the basement rather than the overhead machines. For ordinary engineering conditions overhead is the place for the winding machinery.

*Engineer, Westbrook Elevator Mfg. Co., Inc., Danville, Va.
†Employment Manager, Philadelphia Company, Pittsburgh.

Mr. W. A. Weldin: Mr. James, are you familiar with the installation in the Burlington Building, Chicago, where after a very bad fire in the middle stories, the elevators were put in service almost immediately?

Mr. H. D. James: I do not know about that installation.

Mr. G. E. Flanagan: Some years ago in New York a tall building burned down and the story was published in the papers that a young man 19 years old operated the elevator through the fire. He supposed he had brought everyone down when the signal bell rang again showing that there was some one on the upper floor and older men tried to deter him from going up, telling him he could not possibly make another trip on account of the progress the fire had made, but he determined to respond to the call of duty and made the trip up and got his passenger and was almost down when the safety stop operated and stopped the car, unfortunately, between floors, so that he and his passenger were both burned to death. I would like to ask if such things could happen in present day installations, or can they be prevented?

Mr. H. D. James: I do not know about this particular case.

Mr. L. J. Schwartzman: Which is most economical, the geared or the gearless machines, when using variable-voltage control and having an elevator speed of 400 to 450 feet per minute.

Mr. H. D. James: The high-speed motor is more economical than the low-speed motor, but the gearing represents a loss of power. Some of the published statements regarding the efficiency of worm gearing vary from my experience so that I hesitate to make any assertion as to the difference in efficiency; but it could easily be calculated if the man who manufactures the gearing will give the efficiency of his machine. Ordinarily, the gearless machine is more economical.

APPLICATION OF MODERN FANS TO THE PHYSICAL CONDITIONS OF COAL-MINES

By J. R. Robinson*

For a number of years I was engaged in the designing, manufacture, and installation of mine fans of the Guibal type. At that time it was customary for a mining company to order a fan of a certain diameter of wheel—ten feet, sixteen feet, twenty feet or perhaps twenty-five feet—and to give with the order the quantity of air the fan was supposed to give off. The water gage or pressure was rarely considered. The diameter of the wheel seemed to be the determining factor in the purchase and installation of the fan. The bigger the wheel the more air, was the usual thought in the mind of the purchaser.

These fan installations sometimes proved satisfactory, but in the large majority of cases they were unsatisfactory. Sometimes the installation was satisfactory when first made and then in a few years it became very unsatisfactory. The purchaser would sometimes praise the fan highly when first installed and in a few short years he would "cuss out" the fan and the maker, because his ventilation was unsatisfactory. There seemed to be very little knowledge of the reasons why a fan should be effective when first installed and then become wasteful and inefficient after a few years use. Every one seemed to be puzzled by these occurrences. The best makes of fans were being alternately praised and blamed, one mining man swearing by a certain maker and another equally good mining man swearing at this same maker. It was a puzzle from the point of view of personal relations with these men in a business way, some of the most pleasant and agreeable men losing sense and judgment over the working of a fan, while in almost any other business relation these same men were sane as could be.

At the time I refer to, the Guibal fan was generally made of wood except the shaft, boxes, and spiders, and due to this light construction, the fan was incapable of creating high pressures. About the same time the Capel fan was rapidly coming into use.

*President, Robinson Ventilating Co., Pittsburgh.

It was a steel fan and capable of creating much higher pressures than the wooden Guibal fan. This fan was introduced into the country by a very eccentric character whom many of you can remember. He was very enthusiastic about his fan and many a time I have heard him denouncing someone who found fault with it. This Capel fan frequently failed to perform as expected. The installation being made for a certain quantity of air, the fan would fail to produce that quantity when the trial came off. Then the arguments began, neither the maker nor the purchaser having a very clear idea of why the quantity of air was deficient. In my conversations with him I was never able to learn from him why his fan had failed to perform as expected. If he knew, he wouldn't tell. I have spent a lot of time, studying his work as well as my own and others, and I believe he never had the real reason why his fan failed to deliver the air to the mine as expected. I think his want of knowledge accounted for his hostility to those who showed dissatisfaction with his work.

As this man was considered the best man available for mine ventilation and the application of fans to mines, and I found he was working with empirical formulæ and did not really understand the fundamental principles of the work of the fan in the mine, I determined to find out for myself these fundamental principles.

During my investigations, I found that an ordinary centrifugal fan of any or all designs and makes, when applied to a new mine, invariably passed its air through itself without backing any of the air from the intake orifice, and that often, a few years after the mine had developed, the fan began to back out some of the air and as the mine kept on developing, this backing out condition got worse and worse, and finally the fan wheel went to pieces and a new fan was required. I also observed that when the new fan was first installed it would pass through the mine, let us say, 50,000 cubic feet per minute at a half-inch water gage, and when speeded up, after a few years it would pass through the mine, let us say, 70,000 cubic feet per minute at a two-inch water gage. Now, the speed of the fan necessary to produce two inches water gage is exactly twice that required to produce one half-inch water gage. Why did the fan produce only 20,000 feet more air when running

twice as fast as it did when originally put on the mine? The pressure increased, as might have been expected from the increased speed of the fan, but the quantity of air should have been 100,000 cubic feet instead of only 70,000 cubic feet. Why was this? With the first condition of the mine, had the fan been speeded up to twice its original running speed, the quantity at that time would have been 100,000 cubic feet per minute and the water gage would have been two inches. I had abundant data to confirm this. However, after the lapse of a few years it was a fact that the fan at twice its original speed was passing through the mine only 70,000 cubic feet; but this amount required two inches of water gage pressure to pass it, whereas when the fan was first installed this same two inches pressure would pass 100,000 cubic feet per minute, and, moreover, a lot of air that could not be measured was backing out of the intake orifice of the fan. In my investigation I found that if I could, in the second instance, pass 100,000 cubic feet per minute instead of 70,000 cubic feet, then I would require four inches of water gage instead of two inches, which showed a much worse condition of the mine than had been anticipated.

After investigating many such conditions, I began to compare the orifice of passage of the mine with the orifice of passage of the fan. Most of you will recall from your study of mine ventilation that a mining engineer named Murgue had developed a formula for finding this orifice of passage and had expressed it by the equation $EO = 0.0004 \times \frac{Q}{\sqrt{W\,G}}$ in which EO represents the orifice of passage of the mine or its equivalent orifice, Q the quantity of air passing in cubic feet per minute, and WG the water gage taken at the same time as the air is measured. The water gage is measured in inches and fractions of an inch.

With this formula we can observe a mine as it develops, and can determine its orifice of passage, and with such information we can readily determine why our ventilation is easy or difficult and why we do or do not get the quantity we set out to get.

Now, let us take the case just cited. We set out to get 50,000 cubic feet at one-half inch water gage and ultimately 100,000 cubic feet at two inches water gage. Using Murgue's formula,

we have $EO = 0.0004 \times \frac{50{,}000}{\sqrt{0.5}} = 28 \pm$ square feet, or $EO = 0.0004 \times \frac{100{,}000}{\sqrt{2}} = 28 \pm$ square feet; so we must have the same equivalent orifice to pass 100,000 cubic feet per minute at two inches water gage as to pass 50,000 cubic feet per minute at a half-inch water gage. But you will note that we found 70,000 cubic feet per minute at two inches water gage, instead of 100,000 cubic feet as we had anticipated. Let us apply Murgue's formula and see if we find the difficulty. $EO = 0.0004 \times \frac{70{,}000}{\sqrt{2}} = 19 \pm$ square feet. Instead of 28 square feet as we assumed for our equivalent orifice, we have but 19 square feet. Now, it is obvious that we cannot put 100,000 cubic feet per minute through an orifice equivalent to 19 square feet at two inches water gage when we found that an orifice equivalent to 28 square feet was required.

You will note that this equivalent orifice is the result of all the factors that impede the flow of air through the mine, whether it be rubbing surfaces, falls of roof, regulators, or any other form of obstruction.

In the case above cited, when 70,000 cubic feet are passing, the fan, if properly designed to meet the original condition, will back a portion of its air out of its intake orifice and will work at low efficiency, no matter who made it.

Now, we sometimes meet the opposite condition which is where the equivalent orifice of the mine is increased above what was anticipated, in which case, if the fan is properly designed for the work intended, it will not back a portion of the air from the intake orifice, but will wiredraw the air through the fan; that is, the fan will be required to make more pressure to get the air through itself than is required to pass the air through the mine. So it is extremely important in the designing of the fan that the equivalent orifice of the mine be known, and, after the fan is put to work on the mine, if the equivalent orifice of the mine be changed to any great extent, the fan will not work with a high degree of efficiency.

We frequently hear the mine manager say. "Give me a cer-

tain make of fan." That opinion is established, I have found, by the manager having had a fan of his favorite make on a mine where the equivalent orifice of the fan and the equivalent orifice of the mine were about the same, and some other make of fan on a mine where the equivalent orifice of the fan was not the same as the equivalent orifice of the mine.

Ten or twelve years ago, I was called upon to investigate a mine at Grant Town, W. Va. The property of this mine was in a gaseous district, and required a large quantity of air. The fan in operation was a Capel, 16 feet in diameter (See Fig. 1), passing

Fig. 1. Capel Fan. Grant Town, W. Va.

132,000 cubic feet of air per minute at 2.3 inches water gage, and was at the limit of its capacity and rapidly going to pieces. You will note that the equivalent orifice of this mine was small.

$EO = 0.0004 \times \dfrac{132{,}000}{\sqrt{2.3}} = 36$— square feet. The equivalent orifice of the fan was about 120 square feet. The fan was much too large for the mine. Those in charge decided that they wanted 300,000 cubic feet of air, and they would get the water gage down to nine inches, which meant an equivalent orifice of

$EO = 0.0004 \times \frac{300,000}{\sqrt{9}}$ = 40 square feet. A fan with an equivalent orifice of 40 square feet was placed at this mine and for a few years the orifice of the mine and the orifice of the fan remained about the same. Duing this period the fan worked with the greatest efficiency. About two years ago, an air-shaft was sunk at the back of the mine, and used to short circuit the air. Through the use of this shaft, the mine is now passing 250,000

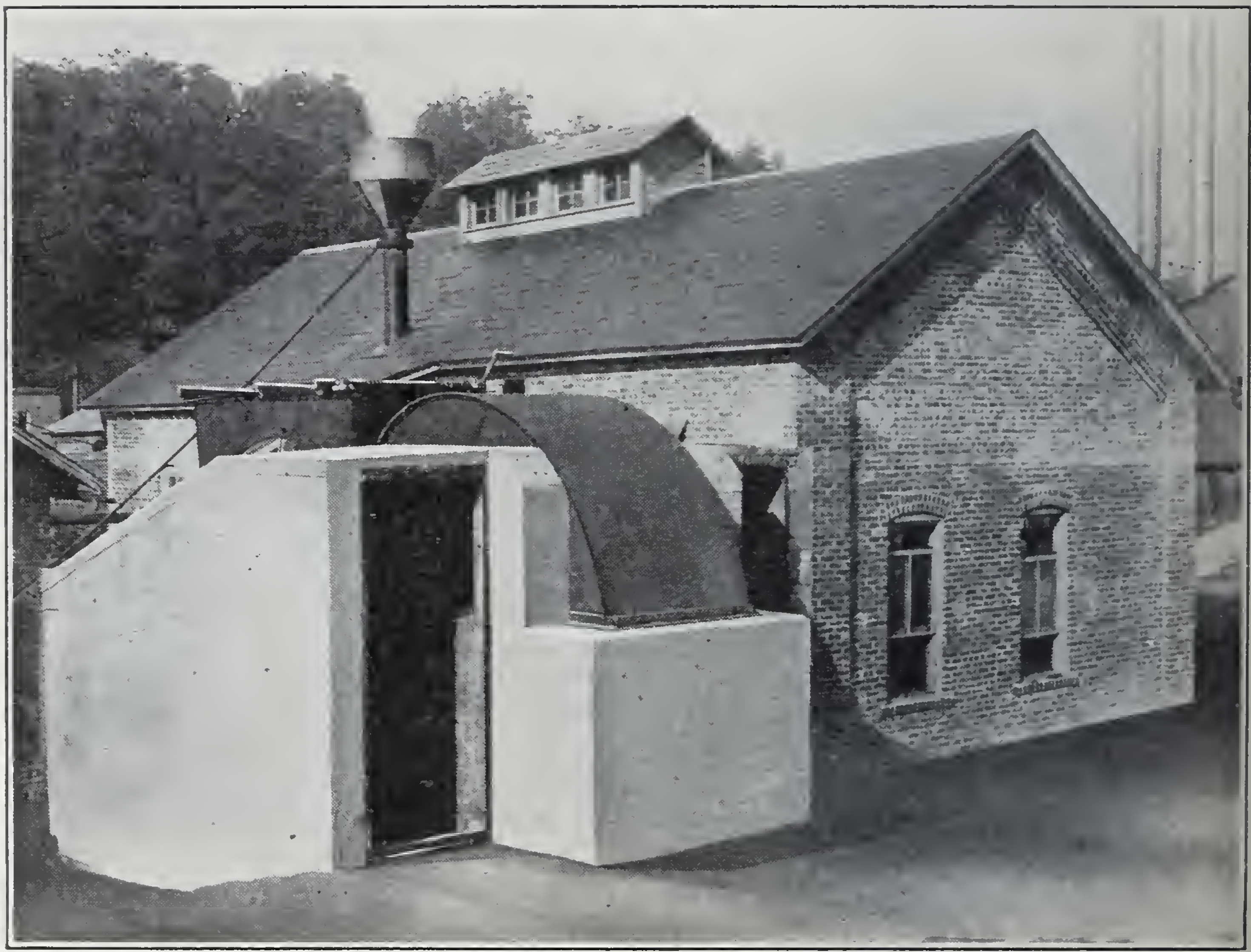

Fig. 2. Robinson Turbine Fan. Grant Town, W. Va.

cubic feet of air per minute at three inches water gage. Now, let us examine this mine in relation to Murgue's formula:

$$EO = 0.0004 \times \frac{250,000}{\sqrt{3}} = 58\text{— square feet.}$$

The mine now has 58 square feet equivalent orifice, and the fan in use has but 40 square feet. The fan, to pass 250,000 cubic

feet of air through itself, must create a much higher pressure than is required to pass the air through the mine. Consequently, it is now a wasteful machine, although it was a very economical and efficient machine before the shaft was sunk and the equivalent orifice of the mine enlarged beyond the equivalent orifice of the fan.

A new fan is being placed at the mine to have an equivalent orifice the same as the mine, and, as long as such conditions ob-

Fig. 3. Installation at Emigh Run, Pa.

tain, this fan will have the greatest efficiency. Let us see what difference there would be in the power applied to operate each fan. It will be remembered that to pass air through two different sized openings requires power inversely as the cube of the size of the openings. The former fan had an orifice of passage of 40 square feet and the new fan has an orifice of passage of 58 square feet. The cube of 40 is 64,000. The cube of 58 is 195,112.

It would require three times as much power to pass the 260,000 cubic feet per minute through the fan with the equivalent orifice of 40 square feet as to pass the same quantity through the fan with the equivalent orifice of 58 square feet when the mine resistance was measured by three inches of water gage. The new fan is shown in Fig. 2.

The Cherry Tree Coal Company has a mine at Emigh Run, Pa., through which the present fan is passing 116,000 cubic feet of air per minute at 5.4 inches water gage (See Fig. 3). Let us see what the equivalent orifice of this mine is:

$$EO = 0.0004 \times \frac{116{,}000}{\sqrt{5.4}} = 19.97 \text{ square feet—nearly}$$

20 square feet. This is not a very large orifice to pass over 100,000 feet of air, but you will note the test taken by the engineers of the Cherry Tree Coal Company below and you will note that the over-all mechanical efficiency is 77 per cent.

This efficiency is very high because the fan is designed for such a mine as this with a small equivalent orifice, and the equivalent orifice of the mine and the equivalent orifice of the fan are practically the same. This mine has had an air-shaft sunk near the back of the mine, and the coal company is now installing at this new air-shaft a new fan which has an equivalent orifice which suits the new equivalent orifice of the mine. The continued use of the present highly efficient fan on this mine, with its enlarged equivalent orifice, would be extremely wasteful of power.

I will now call your attention to a mine where the fluctuating equivalent orifice requires the changing of the fan from a large to a small fan and back again to the large fan. The Lowber Gas Coal Company has a mine near Fayette City, Pa., which has these conditions. The mine was developed in such a manner as to pass 100,000 cubic feet of air per minute at two inches water gage.

The equivalent orifice is, therefore, $EO = 0.0004 \times \dfrac{150{,}000}{\sqrt{2}}$

$= 42$ square feet. An eight-foot steel fan was placed on this mine. Its equivalent orifice was about 45 square feet. It was close to the requirements of the mine when first installed; but, as the mine developed, the quantity of air given off by this fan

was gradually decreased until when I first observed it, there were passing through the mine 87,000 cubic feet of air per minute at 1.2 inches water gage. Let us observe this new condition with the use of Murgue's formula. $EO = 0.0004 \times \frac{87{,}000}{\sqrt{1.2}} = 31.63$ square feet. Instead of the original 42 square feet, the equivalent orifice has dropped to less than 32 square feet. The power required to pass this air with the eight-foot fan originally on the mine was 78 horse-power measured on the brushes of the direct-

Fig. 4. Robinson Turbine Exhaust Fan. Fayette City, Pa.

current-motor used to drive the fan. Thirty horse-power was all that should be required to drive such a load with a suitable fan. Such a fan was installed with an equivalent orifice of about 30 square feet and the saving in power was nearly fifty horse-power. The cost of making the new installation—fan, motor, and belt was approximately $4000, which was saved in the power bill in about eight months. The fan installed was six feet in diameter (See Fig. 4).

The eight-foot fan originally installed was left standing con-

nected to the mine, in anticipation of the sinking of a new air-shaft at the back of the mine, when it is expected that the equivalent orifice of the mine will be enlarged to about 45 square feet. The new shaft will likely be connected to the mine within four years after the time when the temporary fan was installed. In this brief time the temporary installation will have paid for itself out of the power saved, at least six times.

The equivalent orifice of the mine is therefore the basis on which the calculations for a mine fan should be made. Having the equivalent orifice and the quantity and pressure known, we can determine accurately the characteristics of the fan. Knowing the pressure or water gage, we know the speed at which the air must travel as the equivalent of the pressure. With the speed of the air known, we know the speed at which the rim of the fan wheel must run to create the given air pressure and, knowing the speed of the fan wheel and its volumetric capacity, we can determine the width the wheel should be to give off the quantity of air required at the given pressure.

This may seem like a complicated cycle of calculations, but it is all logical and each step follows in succession from the base of all the calculations, which is the orifice of passage of the mine.

DISCUSSION

Mr. H. H. Rankin:* I would like to ask Mr. Robinson to explain a little more fully what he means by the "equivalent orifice."

Mr. J. R. Robinson: The equivalent orifice of a mine or the orifice of the passage of any duct, is the size of opening that will be required in the size of a thin plate to let the air go through in a given quantity at a given pressure.

Mr. H. H. Rankin: Does this mean cubic contents, or length of the passage?

Mr. J. R. Robinson: It resolves into this opening in a thin plate through the various obstructions encountered. That means an enormous number of observations in the mine to determine the constant which is used in this formula, 0.0004 multiplied by the quantity of air divided by the square root of the water gage pressure in inches; that is, $0.0004 \times \frac{Q}{\sqrt{WG}}$. That determines the size of the orifice that will be in the thin plate to let the given quantity of air pass through at the given pressure. This constant 0.0004 was determined by Murgue from a great number of observations.

Mr. W. A. Weldin, *Chairman*:† You spoke of the equivalent orifice of the fan in contradiction to that of the mine. Will you elaborate that a little?

Mr. J. R. Robinson: The orifice of passage of the fan has to be determined by an experiment for each kind of fan. The orifice of passage of the fan is obtained in much the same manner as the orifice of passage of the mine. In these modern fans the orifice of passage varies from 60 to 80 per cent. of the size of the

*Civil and Mining Engineer, Pittsburgh.
†Blum, Weldin & Co., Pittsburgh.

intake orifice when properly designed so that the outlet of the fan shall have the same size as the intake orifice.

MR. W. A. WELDIN: You set it up and force the air through a restriction of some kind to build up the water gage?

MR. J. R. ROBINSON: Yes. To determine that matter accurately we take a tube that is large enough to take care of the fan at its maximum capacity and put doors at the end of that tube so that we can create any pressure the fan is capable of making; and then measure with a Pitot tube in that duct the quantity of air and the pressure as varied by the varying of the openings of the doors at the end of the duct. In that way we can determine the orifice of passage of the fan.

MR. W. A. WELDIN: For a proposed mine where you would have to assume the characteristics you would have to guess very largely.

MR. J. R. ROBINSON: In a coal-mine that is in operation, with a fan installed, it is very simple to determine the orifice of passage of the mine. Of course that varies considerably. One year the orifice of passage of the mine may be 60 per cent. greater than it is the next year. It depends on how the workings are conducted and whether regulators are being used and whether there are auxiliary fans. Using an auxiliary fan in a mine will change the orifice of passage very considerably, and also the use of regulators. I had occasion not long ago to investigate a mine where the management had spent a considerable sum of money cleaning up the airways and then had put regulators in at the end of those same airways and made the equivalent orifice of the mine still smaller. In that particular case they might just as well not have cleaned the airways out for they put back the resistance in the regulators.

MR. J. O. DURKEE:* I understand, from the paper, that the smaller the equivalent orifice, the smaller the fan. Suppose you have an equivalent orifice of 34 feet, that will require, say,

*Mining Engineer, Pittsburgh.

a six-foot fan. If you have an equivalent orifice of 80 feet, you will require possibly a 10-foot fan. The first cost of a 10-foot fan is considerably more than that of a six-foot fan, the first cost of a six-foot fan being about 2/3 that of a 10-foot fan. What would compensate for this difference in first cost? Again, when the equivalent orifice of the mine becomes greater than that of the fan, why do you not decrease the equivalent orifice by erecting a brick wall to close up the air-course partly, and by that means create an equivalent in the mine to suit that of the fan?

MR. J. R. ROBINSON: The small fan with a small equivalent orifice requires a larger quantity of power to drive the same quantity of air through it that would be required with a large fan and a mine with a large equivalent orifice passing the same quantity of air. In fact, you could get that pretty closely in this way. We know that to pass air through any orifice, whether the orifice be large or small, the power required will be inversely as the cube of the orifice.

Taking the case you cited, say roughly 30 and 80 feet, the cube of 3 is 27 and the cube of 8 is 512, so that your power required to pass any quantity of air through the 30-foot opening, compared with the power required to pass the same quantity of air through the 80-foot opening would be as 512 to 27. Buying power, as most of the mines are doing now, where you measure it by meter, it would be absurd to put a small fan in a mine with a large equivalent orifice, because the power necessary to drive the air through the fan itself would be unnecessary to drive it through the mine. The power saved by using a fan with an equivalent orifice to suit the equivalent orifice of the mine would soon pay the cost of the fan.

In the instance I cited they got their money back in eight months through a saving in their power bill. I know of one mine after another where, if this thing I have been discussing this evening were observed, the fans could be replaced out of the power bills in less than a year.

MR. H. H. RANKIN: Will you give us some information on the booster fan?

Mr. J. R. Robinson: I have a good deal of that but I do not know that I have it at my tongue's end. Booster fans generally should be applied at some distant and remote point in the mine where the air cannot be conducted to the faces by the pressure obtained from the primary fan. There are a great many people who think that the booster fan ought to be put in the airway where a good current is flowing to boost the air furnished. That is all a mistake. You cannot get results with a fan placed in an airway where there is a good current of air. When the air is sluggish, in some remote section of the mine, you put in an auxiliary fan that has sufficient capacity to create a pressure to pass the current through that difficult area and deliver it back to the main return current. If you do that, the auxiliary fan should always be used, but if you undertake to put an auxiliary fan in a current where it is going freely it is more an obstruction than a help unless the fan has a capacity to create more pressure than the primary fan is making where the auxiliary fan is applied. If there is enough pressure in the air current to conduct the air through the airway it does not need any booster fan.

Regulators in connection with this matter might be mentioned. Too many people are using regulators to create a pressure so as to cause air to flow in the remote portions of the mine. In that case, your regulator that is put in the mine is damming the air back on the primary fan and creating pressure that, in general, the fan was not intended to make. The consequence of that is that when you get too many regulators in the mine the air is dammed back on the fan and the fan instead of passing the air through itself into the mine passes a portion of it out into the open air. This action of the fan is usually caused by regulators. You can use regulators in a mine to get the air back into the remote portions of the mine, but it is best to use auxiliary fans in the remote air passages.

Mr. H. P. Greenwald:* I should like to ask what is considered good volumetric capacity in modern fans working in mines, whether fans doing 250 or 275 per cent. are doing what they should do.

*Assistant Physicist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

Mr. J. R. Robinson: In general, 250 to 400 per cent. is common practice. The volumetric capacity of the fan can be built up through the designing of the wheel. I have made fans with volumetric capacity of 900 per cent. In mine fans that is not at all desirable. I have found that a fan is best adapted to a mine with about 400 or 500 per cent. Most of our modern fans are running 250 to 400 per cent.

Mr. W. A. Weldin: I think the idea of changing the fan from time to time during the development of the mine is a distinct step ahead. It is wise to plan for such changes in advance and to expect them. I know it is frequent practice to put a large, expensive and high-powered fan in a new mine which has a very small resistance. I believe that is wrong, and I was much interested in Mr. Robinson's suggestion of the saving possible by changing the fan from time to time as the characteristics of the mine change. After a mine is well developed, there may come a time for calling a halt on the increasing air resistance, by cleaning the air-courses, or, introducing more splits, or secondary outlets; and it is interesting to see how advantage can be taken of such changes and, by a little expenditure on a new fan, realize a saving of power.

I would be very much interested some time to see worked out a typical problem of a shaft mine with an assumed constant coal output and constant volume of air. The first workings will be close to the shaft, and the resistance small. As time goes on they will gradually get farther and farther away. Thus the mine resistance will increase, up to a point where some re-arrangement of the ventilation will be indicated. It would be interesting to show the economy of using different fans through the life of such a mine. Of course, in practice, we rarely have a mine of constant output; and, after the first installations, subsequent fans would be prescribed by means of the measurements indicated by Mr. Robinson.

Mr. J. R. Robinson: I don't know whether I fully understand that or not. Do I understand that you want a particular case were a mine starts with a large equivalent orifice and gets

down and down and then through making splits gets its orifice large again?

Mr. W. A. Weldin: My thought is that an assumed or typical condition might be used to show the different stages mathematically by way of illustration of your points. An extreme condition would be a mine with a shaft at one corner of the property, with the main headings constantly extending and the workings getting farther and farther away and the resistance therefore increasing. With the same number of men you would want to circulate the same amount of air, and you would adapt your fans to the changed conditions. There would be a critical time when it would pay to make the change, and before which time it would not be economical to make it.

Mr. J. R. Robinson: It would be according to the power consumed. I think I could get you something like that. I have quite a number of cases of that nature.

Mr. W. A. Weldin: Something of that kind in the history of the property. You have to design your plant for an assumed condition that will be economical at some point or other and will then cease to be economical.

Mr. J. R. Robinson: Then the question would be at what point does the waste become sufficient to justify the installation of a new fan?

Mr. W. A. Weldin: Yes, we always have something like that coming up.

Mr. J. R. Robinson: Yes every mine gets to that point.

Mr. H. P. Greenwald: There is another thing in the work that is not so much a matter of fans as of test methods. I should like to have the speaker point out the method of handling the anemometer in taking air measurements. Some take center readings only and others distribute it. What method gives most satisfactory results?

Mr. J. R. Robinson: That is largely a question of practice of the engineers of the different companies. Quite a number of people make a center test only. The center velocity mounts up to approximately 20 per cent. higher than the mean speed of the air, so that in a mine with rough surfaces the center velocity will not give the mean. Most companies, I think, use about five locations—four at the corners and one in the center—and take the mean of those five readings.

The Frick Coke Company has a peculiar way of measuring that I never saw used elsewhere. This is to take a section of the mine and mark it off by wires into 36 sections, and then cut a hole in the side to let the man back out of the airway. One man holds the anemometer and another holds the watch and they hold it three seconds in each one of those 36 sections. That would give probably the best mean we have any way of getting in a mine, but it is very rarely used. Measuring air is very largely a question of the individual who is doing the measuring.

Mr. W. A. Weldin: I have had some tests along that line. I am sorry Mr. Eavenson could not be here, for I know he has done considerable work along that line. The results were quite interesting. Perhaps we can get him to give us some of that as a written discussion. I remember he used a Pitot tube. The company with which I was connected at the time also used Pitot tubes. We took some precautions similar to those used by the Frick Coke Company, as referred to by Mr. Robinson. For practical purposes in a mine where readings could be taken quickly we arrived, as a sort of mean position, at four spots about equally distant from the middle as giving a very fair average. That was an effort to arrive at a fair measurement without an elaborate scheme of measuring the whole cross-section.

Mr. H. P. Greenwald: My reason for raising that question is that we have recently made some experiments that seemed to show that some bumps would deflect the air current and bunch it on one side of an entry without any apparent reason at all after you had examined the traverse of the section. A center reading would not be mean, and unless you traverse it you do not have

any idea of what the average really is. The center reading might be only 10 per cent. off but in other cases I know it was off at least 25 per cent.

Mr. H. H. Rankin: To get the best results it is sometimes best to take a concreted heading.

Mr. J. R. Robinson: Most airways are so rough that to get anything like accurate results you have to section them. As Mr. Weldin says, it is largely a guessing process, and to use a Pitot tube you must have a good smooth duct.

Mr. W. A. Weldin: There is really no object in getting the air regulated down to a fine point because the total air required is only an approximation. The main thing is to be sure you have enough.

Mr. H. H. Rankin: If there is no more discussion I would like to give a little experience I had about three weeks ago in the Mammoth Cave in Kentucky. They have a passageway 60 feet high and 80 feet wide and, they claim, 150 miles in underground passages going down to a depth of 175 feet below the surface. Is it a practical problem to circulate air through that cave by a fan, or would that require auxiliary fans?

Mr. J. R. Robinson: It seems to ventilate itself. There are thousands and thousands of galleries and most of them are dead ends. It would be pretty hard to ventilate that cave unless you go at it as a dead-end proposition (and some of them are 20 miles long), with a duct and a fan connected at the end, and blow the air into the dead end and let it come back again.

One of the guides told me he had explored over 300 miles of that cave and he knew there was so much more to it that he had never seen that he would not venture to guess as to how many miles there are. So I do not have any idea how you could ventilate it.

PRINCIPLES OF WARFARE, BUSINESS, AND ENGINEERING

By Ralph Rainsford*

The subject of my talk sounds rather formidable as I listened to it read by our Chairman. I want to assure you that what I have in mind is a very simple matter. I shall not make any statements of principles that are not self evident; but if I can present them to you so that they will attract your interest as they have attracted mine, so that you will give them some further thought and application, I shall be well rewarded for my effort.

I have been a student of military history and always much interested in the weapons of war both ancient and modern, so when I went to train at Plattsburg I foolishly imagined that besides trying to teach us the rudimentary elements of the soldier business, my instructors would at times lecture on the principles of war or refer me to text-books where those principles were enunciated in primer form. Most of you know that I was foredoomed to disappointment. Instead of appealing to my intelligence, they gave me pages and pages of Infantry Drill Regulations, Interior Guard Duty, etc., to memorize. As one student officer said, "They gave me a number, everybody barks at me, and I answer to a dog whistle."

However, in the course of time I emerged from the obscurity of the rear rank, rose to top sergeant, and finally to first lieutenant and got a chance to handle my platoon and sometimes the company in sham battle. I shall never forget that first week on the "hike." It was one of amazing disaster. The umpires killed me off three times on three successive days, and the Second Cavalry, regular army, finally captured me and the remnant of the company on the fourth day.

In despair I went to my Major, afterwards General Stewart, and asked for some book on first principles. I recognized my blunders and the complete failure of the time schedule, but still believed there were some cardinal principles which, if I could grasp them, would open up a new world of possibilities. Greatly to my surprise, the Major, though he pointed out my errors, could

*Chief Engineer, Philadelphia Co., Pittsburgh.

not even tell me in so many words what were the principles of Napoleon, which the war correspondents so glibly referred to. It was not until after the war that I found them, in a book written expressly for that purpose by General Townshend*, because in no other place were they clearly set forth in the English language.

You will recall that by the time of the Franco-Prussian War, the French had completely forgotten the lessons of the Great Napoleon, but the Prussians had learned them by heart. By 1914, the French were again followers and students of Napoleon, the Germans had never ceased to be, but the English and ourselves knew nothing about him. The English have since taken up Napoleon, but we have not in this country, so far as I know.

I have emphasized Napoleon because he was not only a great military genius, but also because as a student of military history, he codified the wisdom of his predecessors, drew attention to the principles that governed the great generals of the past, showed that they were unchanging principles and made them his own.

I do not intend to outline these principles at length and show their application to civil life, whether business or engineering. It would be easy to do so, but you can do that at your leisure. I prefer rather to mention them briefly and then take up the method of their application. Why I intend to devote my time this evening to the method of applying a principle rather than to the principle itself is because the principles are self evident; they have only to be stated to be recognized as old friends, while the application of them involves us in much hard work and constructive thinking. Briefly the principles are:

1. The objective—the goal to be reached, or the mission to be accomplished. In a major advance by an army, it is known by all from general to private. Yet how often is the mission of an advance guard forgotten when the first shots are fired. Also, how many employees of any company could clearly and unhesitatingly state what is the objective of their employer. In civil life it is generally assumed, not stated, and is for that reason nebulous and uncertain.

2. Economy of force—concentration of effectives, avoid-

*My Campaign in Mesopotamia, by Major-General Sir Charles V. F. Townshend. 1920. T. Butterworth, London.

ance of dissemination, and simultaneous effort towards the objective. In other words, do not try to do too many things at once, and leave the secondary objectives until the men or money can be spared. A good example of the proper application of this principle is the handling of the British Navy in the late war. It was concentrated in the North Sea and by its larger size blockaded the German Navy throughout the war. It did not have to win the battle of Jutland. Although the Germans got the better of that engagement, they never dared try again.

3. Strategic offensive. There is no use of being always on the defensive. Only the offensive, or in civil life initiative, will bring results. Naturally the offensive in war is directed at the enemy's weakest point; in everyday life, where the result will best repay the effort.

4. Rapidity or economy of direction—the shortest or the most judicious road to the objective sought. The longest way round may be the quickest way home. Your progress toward your objective must not be too greatly hindered. The quicker you start the sooner you will arrive.

5. Security. If your plans are to be carried out, you must have liberty of action. In war, you will cover your danger points with outguards, or flanking parties, etc., and in civil life, take out life insurance, provide duplicate equipment, and build to withstand unusual strains and accident.

That is all. There are only five points—objective, mass or economy of force, offensive, economy of direction, and security. Of course, volumes have been written about their application. They are so simple, so common-sense, it hardly seems worth while to mention them. Yet there are few men who can keep them all constantly in mind in considering any problem, whether in warfare or peace; and no general of whom I have ever heard, in going down to defeat, failed to violate at least one and generally several in a single operation. I believe also that these principles are equally applicable to business and engineering, and that no individual or corporation ever failed without violating these principles wholesale.

I do not mean to say that war, business, and engineering can be reduced to rules and that success or failure will ensue as these

rules are obeyed or violated. They are not rules but principles. A man must be very wide awake when he judges his actions by them. A great man, a genius, will sometimes appear to violate them, and may actually do so, deliberately taking the risk in the hope of greater gain, but he knows what he is doing. The trouble is that most defeated generals have been in complete ignorance of the principles they violated and few of us in our daily life sit down to plan deliberately, or, having determined on our objective, have the patience and skill to work out the details for success as logistics aim to do in the military art.

Such things have nearly always been better done in navies than in armies and for perfectly logical reasons. A ship cannot leave the dock without coal to drive her boilers, and without some sort of a crew; and the crew will not go aboard without some assurance that food is aboard. The very nature of the case drove naval officers into logistics—the study of the things necessary to be prepared in advance. But an army was on land, it walked on its own feet, and if it was not too large it could obtain some sustenance from the land. Whether it could fight was another question, generally merely assumed, along with such details as rifles, cannon, equipment and shoes.

You will recall Bryan's famous saying that if this country was forced into war, "A million men would spring to arms over night." He failed to mention where the arms were coming from. Logistics never bothered Mr. Bryan.

I have outlined the major principles of strategy: Objective, economy of force and the mass, offensive, rapidity, and security. The question in continental armies was how to drive these principles into the heads of the officers attending the war colleges. War is an extremely serious business. Errors are very costly and sometimes fatal. Therefore, it would not do to take any chances, and serious-minded and logical people like the Germans proceeded to analyze the problem in detail. They studied history; they studied Napoleon. They found that the principles of strategy had not changed from the earliest recorded history to the present time, although tactics changed with the weapons employed. Given a well disciplined army the problem then was to train the minds of the officers to think correctly.

On this point the Germans made a great contribution to strategy. They evolved a standard method for the solution of any strategic problem, called the "estimate of the situation." By this method any problem is divided into four parts:

1. The objective or mission.
2. The difficulties to be overcome.
3. The resources available.
4. The decision or plan.

This was the method adopted by the German general staff in the wars of 1866 and 1870 and it worked so well in war that the German government adopted it in solving civil problems. The phenomenal commercial and industrial growth of the German Empire from 1871 to 1914 was the wonder, envy and worry of all Europe, and I do not believe it would have been possible without the correct thinking and logical conclusions to which the Germans were aided by the habitual use of the estimate of the situation method.

Of course, this method merely reduces to a formula or equation the various steps necessary in any sound reasoning, and steps which are almost invariably followed in engineering construction, such as the building of a bridge. Yet it is safe to say that this method is not being followed in the planning of bridges on government authority by the city and county. I do not mean that the engineers of the city or county are at fault. I assume, of course, that they will design a suitable structure; but the estimate of the difficulties to be overcome, which are chiefly financial, and the estimate of the financial resources are seldom properly prepared or compared.

The more definite a problem the more clear cut will be its solution. Hence problems in administration do not as readily lend themselves to analyses as a problem in engineering design. When it comes down to building a structure, no one could succeed who had not consciously or unconsciously treated the problem as required by the estimate of the situation method. The four points you may remember were (1) objective; (2) difficulties; (3) resources; and (4) decision; but in practice the engineer does not properly sum up the difficulties, or even the resources.

The resources eventually translate themselves into the money

available for the project, and the engineer is very apt to assume it will be forthcoming; otherwise the problem would not be in his hands. It is the business of someone else to raise the capital, and he seldom worries about that. Right here he makes a great mistake. If the engineer is not keenly interested in the cost of his project and in the financing of it, he not only lacks the urge to produce the most economical design, but also sooner or later he will let his employer or client in for a radically bad piece of engineering. By this I mean that a good piece of engineering is the simplest and cheapest design that will give the required results. The product must be judged not only from the standard of performance, but also of economy. The estimates are not something to be exceeded, but "bogys" beyond which expenditures must not go.

Most of us have no conception of the poor repute of engineers with financiers. It is because of the uncertainty as to the number of dollars they are actually going to spend. Land can be bought at a fixed price; materials can be secured at stated figures; the personnel can be hired. Then the engineers begin to submit estimates of the cost of future projects, and if they are not watched and controlled very closely they will succeed in involving the capitalist in far greater expenditures than were originally contemplated. Some cynic, I forget who, said that a wealthy man could drink and gamble and still retain his wealth. He could even become involved with women and survive, but if he placed his trust in engineers, he would eventually and inevitably be ruined.

So much for the resources. Now as to the difficulties. Finances come to the fore, but we have covered that. Roosevelt, in his autobiography,* mentions an officer in charge of some division of the War Department at Washington at the time of the Spanish War. The officer bitterly complained to Colonel Roosevelt, saying that his office was running so smoothly until the war came along and upset everything. That officer's plans had not even taken into account the main object for which his organization was created. He had no plans ready to meet the great crisis for which the army itself is created and maintained.

*Theodore Roosevelt; an Autobiography. 1913. MacMillan, New York.

We can afford to laugh at the "arm-chair" officer, but how about our own jobs? The public-utility companies that I represent are charged with the duty of giving service. Recently the electrical division got up a plan, after a great deal of study, for rebuilding the network of electric circuits that give light and power in the down-town Triangle of Pittsburgh. The electric art has grown by leaps and bounds so that we have inherited all the things good and bad that our predecessors did and the structure must be rebuilt and systematized. These electrical engineers produced an excellent plan and brought it to me for approval. It was the work of many months. Electrically, I had no doubt that it was an excellent plan. I looked at it. I tried to look as though I completely comprehended it, and the more I looked at it, the more the conclusion was forced upon me that all that was wanted of me was to sign on the dotted line and not waste the valuable time of any hard-worked staff by asking unnecessary questions. I had my pen poised; then I began for the first time to think, what is the purpose of this plan—its objective? To serve the down-town Triangle efficiently, continuously, come hell or high water. That was enough. Immediately I saw my line of criticism. Had the engineer taken due account of flood? Oh, yes, here was the high-water mark. Of fire? No not particularly. Well fire and flood often go hand in hand. I will flood your city to the high-water mark and then I will have a big fire in this block (indicating a certain point). Now what have I done? He said "Oh, hell, half of the city is in darkness."

That engineer is an exceptionally good one, but had not fully taken into account the difficulties due to the elements. Electrical difficulties, his own specialty, he had followed with a fine-tooth comb, but he had not fully reckoned with the elements.

I referred a while ago to the problem facing the continental war colleges—a problem which the studious Germans very frankly faced. A few brilliant men had revived the Napoleonic principles and devised a formula for the solution of problems. What was required was to make this knowledge common to all their army and navy officers and to teach them how to think. They did not want to take any chances and they started at the very root of the matter when they taught the officers how to think.

Apparently it is perfectly possible to go through a whole course of instruction from kindergarten to post-graduate college course, without being taught how to think. Mathematics, grammar, Latin and Greek are excellent exercises in thinking and reasoning, but one can, so to speak, lock up one's knowledge of each of them in a separate compartment of his mind, and only apply to each the particular kind of reasoning required, and never apply it at all in any other sphere of activity whatsoever.

My own experience convinces me that most students need to have pointed out to them not only the necessity for thought, but also the mechanism for applying thought. I learned my lesson by accident, but the circumstances made a vivid and lasting impression on my imagination, and I find the estimate of the situation method extremely useful. In fact, I have organized the work in the Engineering Department of the Philadelphia Company along that line, with a Planning Division whose duties much resemble those of a General Staff of War and Navy, and with a method of procedure in laying out a job, for which I cannot claim originality, but to which I was driven step by step by the estimate of the situation method.

Objective, difficulties, resources—these will be followed, first, by planning; second, by securing the means wherewith to do; and, third, by doing. In military language, planning belongs to strategy; procuring the means belongs to logistics; and the doing of a thing belongs to tactics. The three steps are quite separate, and for their best accomplishment require rather different temperaments and qualifications. The brains and imagination required for the planning of strategy are not necessarily combined with the organizing and executive ability required for logistics or tactics. If you think of logistics as the service of supply, including the detail design and production of engines of war such as new types of battleships, aeroplanes, etc., you will note that the problem to be solved by logistics is outlined by strategy, and that the men and material produced by logistics, are operated by tactics in accordance with the plan laid down by strategy. I am sure that if our problems in civil life, say those of any individual company, were as clearly parceled out to separate parts of the organization as they are—not in this country, but in a good

Foreign War Department, many mistakes in organization would be avoided.

During the war I made a report on the British Air Service method of organization, and had at my disposal an enormous mass of information and the help of two British officers who were thoroughly versed in it. The problem was to condense the salient points into a short report that would be read and excite sufficient interest to ask for more detail. On paper, the British Air Service was the best and most ingenious organization that I have ever seen. It began with the Air Ministry—like a board of directors, only composed of competent specialists representing the usual officers, general manager, secretary, treasurer, controller, chief engineer, a representative of the Air Staff and a representative of the Ministry of Munitions. The requirements of strategy were laid before the Board by the Chief of the Air Staff. What he told them of campaign plans I do not know, but he laid down the requirements for logistics to work out. For instance, he would produce a plan calling for so many squadrons of each type of plane and give the requirements of each type. By this I mean that in specifying a combat plane he would comment upon the good and bad points of present types and then proceed to demand a plane capable of at least so many miles an hour, of remaining aloft so many hours, and of attaining a certain height. As for delivery, he wanted them yesterday; but that was what the rest of the Board was for. They told him they did not have the men, the money, or the materials, but perhaps they could do so and so and commence delivery in six months; and so a compromise was worked out and scheduled. It was scheduled in complete detail, not only for deliveries, but to dovetail in with squadrons to be replaced on all the numerous fronts where the British were operating from England and Archangel to Mesopotamia and East Africa.

There was a chart of renewals and replacements covering a six-months period and detailing every wing or squadron in service on all the fronts, the date it was due to be withdrawn, where it would go, and where the replacement would come from. That schedule was said to be accurate within about two weeks of time, and was probably no more subject to change than is the produc-

tion program of the average industrial company. It was a magnificent piece of scheduling, of logistics—something that up to the time of the Armistice, which came a few months later, we were quite incapable of duplicating. Why we were incapable is another story. The war is over and we will not fight it over again to-night, but I wanted to give this example of a problem outlined by strategy and carried out in minute detail by logistics, because it so closely parallels our problems in civil life as they confront the business man and the engineer.

You can all see, without my expanding the illustration, the part the engineer played in inventing, developing, manufacturing and scheduling the air fleet the requirements of which were set forth by the Chief of the British Air Staff; but, of course, the eminent gentleman was also aided and abetted by engineers, if he was not a first-class engineer himself. In fact, it has always been hard for me to imagine a great strategist who was not at least something of an engineer as well as a far-seeing person with great imagination.

The great military strategists like Alexander the Great, Cæsar, and Napoleon were great engineers and inventors also. They were geniuses, but my object this evening is to point out that they left behind them certain simple principles—self-evident truths applicable not only to warfare but also to government, business, and engineering; that, later, the methodical Germans thought so much of these principles that they applied them not only to war, but also to business and engineering, and did so with most conspicuous success; and, wishing the knowledge of these principles to be the common property of all those in command, they evolved a method for the solution of problems of war, and government business, which method is called the estimate of the situation. By this method the objective sought is first clearly defined, then the difficulties are studied, and then the resources. The final plan can then be undertaken rationally.

In our every-day life we follow this sequence unconsciously; but, because it is unconscious, neither the objective, the difficulties, nor the resources are defined as clearly as they should be.

I was riding to work the other morning in the street-car and stood up all the way from Squirrel Hill to Grant Street. Beside

me was another man who complained of the service that compelled him to stand. He "cussed" the management and kicked at the 8 1/3-cent fare. I listened to him until he ran down, and everyone near by was listening to him and silently backing him up. I said "What do you want first, better service or a five-cent fare? You know perfectly well you can't have both now." He looked at me and said: "I vote for service. I would rather pay 10 cents and get a seat and more speed;" and the crowd seemed to agree with him. In other words, he had not even defined his real wants—his objective—yet only a few seconds reflection as to what his objective really was, made his conclusions rational.

We have an 8 1/3-cent fare in Pittsburgh to-day because five years ago nobody would stop to inquire what were the difficulties and what the resources of the Pittsburgh Railways Company. The management's objective was to continue to operate and to give service. The public's unthinking objective was a five-cent fare, and they brushed aside the question of difficulties and resources by saying, "The company is rich," or by the still more intellectual argument of "Five cents is enough." The company went into a receivership, and, whereas a seven-cent fare might have saved them, they were directed by the court to charge 8 1/3 cents, and that fare will have to remain until service—the true objective of the company—is actually established, and that is some years off.

We started out with the principle of strategy and have ended with our local municipal problems. I have tried to show that they should both be approached in the same manner.

DISCUSSION

Mr. Morris Knowles, *Chairman*:* We have listened to a most unusual, unique and interesting talk by one who has had experience in the field of warfare and in the field of civil life—one who is helping to solve the problems of life in this community. There must be many here who have had somewhat similiar experience in different lines who would like to speak, either in agreement or in controversy with some of the remarks of the author. Major Bell, you have had some military experiences along this line; may we not hear from you?

Major J. F. Bell:† Abe Martin said the other morning that there is nothing new in the Coué theory of telling yourself that you are getting better and better every day. He said "Lots of us Americans have been kidding ourselves that way for years". We Americans are likely to "kid" ourselves regarding our national ability and our personal ability, and it is a good thing. It leads to confidence. It gives us morale in our nation and morale in our organizations. But we don't want to fool ourselves. There is no royal road to learning. It takes time to learn anything. You may read a book on bridge—not the structure but the game—and you may think you know something about it after you get through. But, when you have played the game with good players for several months, you will begin to appreciate the fact that you don't know very much about it. You may read a book on foot-ball and think that you know something about foot-ball. The greatest coach I have ever known once said that there are only three things for a line man to do, either in offense or defense—he goes straight ahead, he goes to the right, or he goes to the left; and still they spend years training line men how to play the game.

I cannot answer the question that Captain Rainsford put to us but I can give you a few references and suggest that any person interested in the military policies and their application in civil life (and they have applications, because there is little difference between war and peace in the general scope and plan in which engineering operations are carried on) some of the books by

*President, Morris Knowles, Inc., Pittsburgh.
†U. S. Engineer Office, Pittsburgh.

Lieut. G. J. Fiebeger*. You can get all those books from the Carnegie Library of Pittsburgh or almost any library, I suppose.

As I said, there is little difference in the scope of engineering operations in war and peace. In war, however, nearly everything is done under different conditions. It is well for us to remember that it was 18 months from the time we declared war until we began our first real offensive at the San Mihiel salient, and we were more ready to go to war in 1917—because our industries and the temper of our people had been built up to it—than we would be under normal conditions. We should remember also that when we did start that offensive in the San Mihiel salient, it was done with two of the greatest nations of earth on each side of us and with borrowed artillery and borrowed airplanes.

I will give you a little of my experience. When the Argonne fight started, the chief engineer of the First Army, needing to devote all his attention to the Muese-Argonne sector, placed me in charge of the engineering operations in the San Mihiel salient, to get things in shape in an enginering way there. I had had 20 years' military training and I had worked as hard as must civilians in trying to prepare myself for just such an emergency. We had to provide for railroad construction and operation, roads, electric light, power, water-supply, and construction of all kinds—every kind of engineering that you have in civil life and a few extra. And the thing that impressed me most was how little I knew about my job. No military man knows as much as he should about military work. We are likely to let down in peace time. We must continue to apply engineering service in war. Wars have not ceased. I believe Senator Pepper said there are five wars going on now. I have not tried to count them up lately, but there are always wars going on.

We in the regular service are supposed to devote a greater proportion of our time to war preparation than the engineers of the National Guard or those of the Reserve; but it is the duty of all of us to learn as much of the application of engineering to war as we can conveniently, and do not get the idea that because you are a specialist in engineering you know all about applying

*Elements of Strategy. 1920. John Wiley & Sons, New York; Permanent Fortification. 1900. H. Charnowitz, New York; Text-Book on Field Fortification. Ed. 3. 1913. John Wiley & Sons, New York.

that special knowledge in war time. I was in command of a specialist regiment during the war and I had charge of other troops who were specialists, and I was guilty of saying, at one time, that as long as I could keep an engineer away from the kind of work he did in peace time I had some hope of him. He was likely to overdo it. I had an engineer in charge of the shops at Gièvres who turned out over 300 jobs before he had his first building half done. That man knew how to go to war. He was building those shops up for the sake of all the troops and not for the sake of the shops. I had, in charge of other shops, officers whose primary object seemed to be to build up shops as they would in peace time, and by the time they had the shops finished the need for them was about over. You officers that served during the World War owe it to your country to help the Reserve along. Join it and help get it started. You do not need to devote a great deal of time to it. You need to do some reading; you need to do some thinking; so that you can apply what you know when war comes, not only for the benefit of your country, but also so as to do justice to yourself.

I am sorry I have taken up so much time. I have rather reversed the point of view of Captain Rainsford, but I thank you for your attention.

Mr. Morris Knowles, *Chairman*: I had hoped that Major Bell might have referred to the remarks in Captain Rainsford's paper as to the carelessness with which some view the flood question in this city. We have not suffered any river disaster for many years and it is rather easy for those in civil life to forget that we may have a great disaster which will not only put our great utilities out of service, but also put us to a great deal of inconvenience and upset our daily life for a few days. We fail to remember that we have had floods that put our entire marginal down-town region out of service, and it is not beyond the realms of possibility that we may have a flood ten feet higher than anything we have had, and high water come up Smithfield Street to the Oliver Building. Of course, the great problem of civic engineering is to what extent it is worth while to prepare for such an infrequent catastrophe.

MR. T. FITZGERALD:* I am one of those hopeless ones, referred to by a previous speaker, who were put on their own jobs in the army. I would like to call attention to the human side of the army game. We had lots of good engineers in the army, but the human equation was the feature that impressed me. I can illustrate by a little incident. To determine whether or not our outfit was well enough trained to go to the front, we were given a problem to work out to get ammunition from four different dumps and deliver it to 24 different battery positions. The job was assigned to the best officer in the outfit. After a short time I went to look him up and found him located at the most important point, the powder dump. I asked him how the rest of the problem was being worked out. His answer was, "I don't know. I turned part of it over to Sergeant Watterson and gave him the only map I had and I don't know what he has done." Well, I hunted up Sergeant Watterson. He said, "Yes, I sent some of it up and turned the rest over to Corporal Somebody." I found Corporal Somebody and he said, "Yes, I took some up and got somebody else to take some more." Parts of the work had been taken over and passed on to others by truck drivers. That problem was performed 100 per cent. I am not attempting to minimize the necessity for sound principles and theories and definite objectives, but do want to point out the overwhelming importance of the human equation. Almost all of whatever success the American Army may have achieved in the World War was due to the individual bravery, resourcefulness and ability of the average enlisted man.

MR. G. E. FLANAGAN:† I was thinking of the remark the Chairman made regarding the 10-foot increase of water stage and it recalled an incident in my personal experience that bears that out about 20 per cent. During the greatest flood we ever had in Pittsburgh, I was with the Dravo Contracting Company, engaged in building a power-house on the South Side, and they took note of the highest recorded stage and determined to be on the safe side and placed their line two feet higher. When the water began to rise everybody was congratulating himself that this new powerplant was above possible flood stage, and would be perfectly safe.

*Consulting Electric Railway Engineer, Pittsburgh.
†Mechanical Engineer, Heyl & Patterson, Inc., Pittsburgh.

The water rose two feet higher than ever before and came to within just one inch of getting in on the floor. As a matter of fact, it did get in through something that had been overlooked. As Major Bell said, we did not work hard enough at the problem and see to every possibility and minor detail and keep insistently at it.

In connection with the plant was a large well for the inlet to the supply pumps and containing the screens and valves, and as the top of this well was below water at flood stage, it was covered over but was provided with two 30-inch manholes. They were perfectly water tight so that the river might flow over them without getting into the building in that way. They were sealed up properly, as the water rose, but someone overlooked a four-inch diameter hole left in the building foundation for temporary use during construction, and the water coming in through this small pipe rose until it sealed the opening between the building and the inlet well trapping the air in the latter until the increasing pressure lifted a manhole cover and let the river in through a thirty-inch diameter opening.

Mr. Morris Knowles, *Chairman*: It is the thing we forget, oftentimes, that determines the difference between success and failure.

Mr. A. E. Anderson:* At the time of the big flood, the remark was made in the hearing of a newspaper man, that we might have a flood of 50 feet. What is the reason we have not had a 50-foot flood? If the rain had been as heavy all over the watershed as it was in Pittsburgh, we would have had a flood of more than 50 feet. If you will look at the map you will see that the reason we have not had such a flood is that the two rivers run almost north and south so that very rarely do they both pour their floods into the harbor at the same time. And the protection has been that with a flood in one river, boats can go around into the other river and be protected.

I was very much interested in the paper to-night because it brought in a new angle with regard to the application of these principles. To me the most impressive part of the lecture was

*Attorney, Pittsburgh.

the closing part and I don't know but what the Society ought to send to the Kaiser a radiogram saying that the princples of war which he exercised for some forty years had the most pronounced effect five years after the war was over, in conquering a strap hanger on the Pittsburgh Railways, as related by the speaker.

MR. RALPH RAINSFORD: It has always been questioned whether the men in the service had the point of view of the training officers. I know they made us memorize page after page until we were ready to shoot them if we got a chance. There was a perfectly good reason for this memorizing. I remember one night in camp, a little while before the Armistice, we had a fire and I had a lot of absolutely green drafted men. We had been instructing them in guard duty, trying to get them to memorize the duties of a guard. When the test came, they remembered what was their duty and were ready. We owe to the West Pointers everything in the way of discipline. It would not have been possible without them to have had our army as it was. The only quarrel was that they said "Do this", instead of ever explaining why we should do it. However, it finally dawned upon our intellects why it was necessary to memorize these things, for in times of confusion one could recall the verbal or written instruction and what was the objective or mission.

MR. MORRIS KNOWLES, *Chairman*: Captain Rainsford has enunciated one of the first principles of life, namely "to learn to obey". Sometimes we later learn why we obey.

PRESENT PRACTICE IN THE DESIGN AND SINKING OF MINE SHAFTS

By R. G. Johnson*

I am glad to have the opportunity to present to you this evening a rather brief discussion of mine-shaft sinking, for your Mr. Eavenson when he asked me to present this subject said that it had been a number of years since a paper on this branch of mining engineering and construction had been given.

Vertical shafts and inclined shafts—we call them simply shafts and slopes—are necessary openings for the raising of coal from the seams to tipples on the surface when the level of the coal seam is below the railroad tracks at the mine. Shafts are equally necessary for the ventilation of mines.

One can readily see that the location, the design, the construction and the equipping of the shaft or slope are most vital duties of the mining engineer whom the operator has commissioned to lay out and construct the works of the mine. May I ask before I go further that I be pardoned if in my paper I define in too much detail certain terms used in shaft work the meanings of which are not obvious? To engineers in mining work such explanations will seem useless. To those to whom the subject is strange such explanations may be of help.

The problem of the location of the hoist shaft or slope I shall touch very briefly, for it is a matter admitting of endless discussion, and the location does not intimately concern the shaft itself. When a field of coal is to be opened intelligently, the topography of both coal and surface must be known. The contours of the coal, while not determinable practically to the degree that the surface can be mapped, can be plotted accurately enough for all reasonable purposes from the sections of diamond-drill holes and other known elevations in surrounding mines. It is strongly advisable to block out a field in 3000-foot or 4000-foot squares and drill at each corner with a diamond-drill, rather than with a churn-drill, for with a diamond-drill the core is saved and the depth and structure of the coal and its roof and bottom measures are definitely determined.

*President, R. G. Johnson Co., Pittsburgh.

With the topography of the coal known, the location of the hoist shaft can then be determined. The shaft is merely the connecting link between the most available, economical concentrating point for the mine cars of coal from the mine with the most economical point to load into coal cars on the surface. Seldom does it happen that the most available spot for plant construction with its railroad sidings, power buildings and near-by town sites comes directly over the top of the best shaft bottom location, a point to which the mine loads can be moved with least power and time, and the empties returned to the working places likewise with the least expense. Engineering studies must be made and top costs balanced with underground savings, or top savings balanced with underground costs, to determine the shaft location.

With the location determined, selection of the scheme of bringing the coal to the tipple must be made; that is, if the coal is reasonably shallow, whether a shaft is the more economical and desirable or whether a slope is to be installed. This is a big subject in itself, and its discussion hardly comes within our province to-night. I may say, however, that 15 years ago, if the coal was under 100 feet in depth, the leaning of opinion was toward a slope, with chain or straight trip haulage. To-day with the successful operation of rubber-belt and steel-apron conveyors in slopes, many prefer a slope for coal up to 200 feet in depth. Balanced self-dumping cages for shafts still remain the most generally used, and are withal the cheapest means of bringing coal to the tipple in cars. If the breakage of the coal is of no importance and large tonnage is desired from a long-lived field, the use of skips for hoisting is figured by many to prove the best investment. If the coal is deep, skips can hoist more cheaply than cages, for greater quantities can be carried for practically the same bottom cost.

Let us assume that we are to open a field of coal that will last 40 years, the depth requiring shafts 300 feet deep; and, by discussion of the various types with their details, design the shafts and then proceed with the sinking according to specifications fitted to our design. The location is determined and we are to use self-dumping cages. For best handling the many operations necessary in the mining of coal in this section a shaft mine must have at least

two passageways to the surface for the cages, a man escape way, which may be either a stairway or a cage way for men, material, and slate-handling cage, an airway for the fan, a return airway, and a pipe way. Aside from the fact that state laws specify that there should be two distinct openings to the surface available for every mine, the shaft-bottom lay-outs and the plan of air-courses in the mine practically dictate that the escape-way and one airway shall be in one shaft, and the coal-hoisting compartments and the other airway in another shaft, with the pipe way placed in either opening according to the mining engineer's pump-room lay-out.

In designing the shafts, the operator decides on a certain output per day to which his mine will ultimately develop. On his acreage—that is, the value of his holding—will largely depend the size and character of plant which he can afford to install. His daily output will determine the size, and the estimated life of the mine will determine largely the character of equipment.

When his output is determined—that is, the number of cars to be hoisted—the size of the car is determined. The thickness of the vein, or rather height of coal to be mined, and the grades, etc., determine within certain economical shoveling limits the height of the mine car, and the area of the car is readily figured when its cubical contents are specified. Roof and bottom conditions are also factors in determining the size of the car to be used, and practical experience with these conditions in neighborhood mines in the same seam really constitutes the best guide in determining finally the size of the car.

The width of the shaft can then be determined, always allowing enough over the length from bumper to bumper to prevent the link from hitting the shaft lining. There should be at least four inches clearance at the ends of the cages to allow for possibility of irregularity in the concrete lining and for possible accumulation of ice, since the hoist compartments must be either neutral or downcast. The cage bearing the car is generally a matter of design for the various cage makers, whose structural details often differ. In fixing the gage of the guides—that is, the distance between the faces of the guides on which the cages slide—the cage maker's dimensions should govern. An allowance of about three-

eighths of an inch should be made on each shoe of the cage to give play to the running of the cage on the guides.

With the space required for the cages fixed, the other necessary requirements are area for the ventilating air of the mine, unless the shaft is part of a system of three or more and is neutral regarding ventilation, and area for wires and pipes. At this point in the design the character of the lining must be fixed, for all shafts require a lining to protect the earth or rock sides from falling, and as walls to hold the ends of the buntons which support the cage guides. The character of the lining chosen practically decides many other details.

Until 1903 most of the shafts for the coal-mines in this

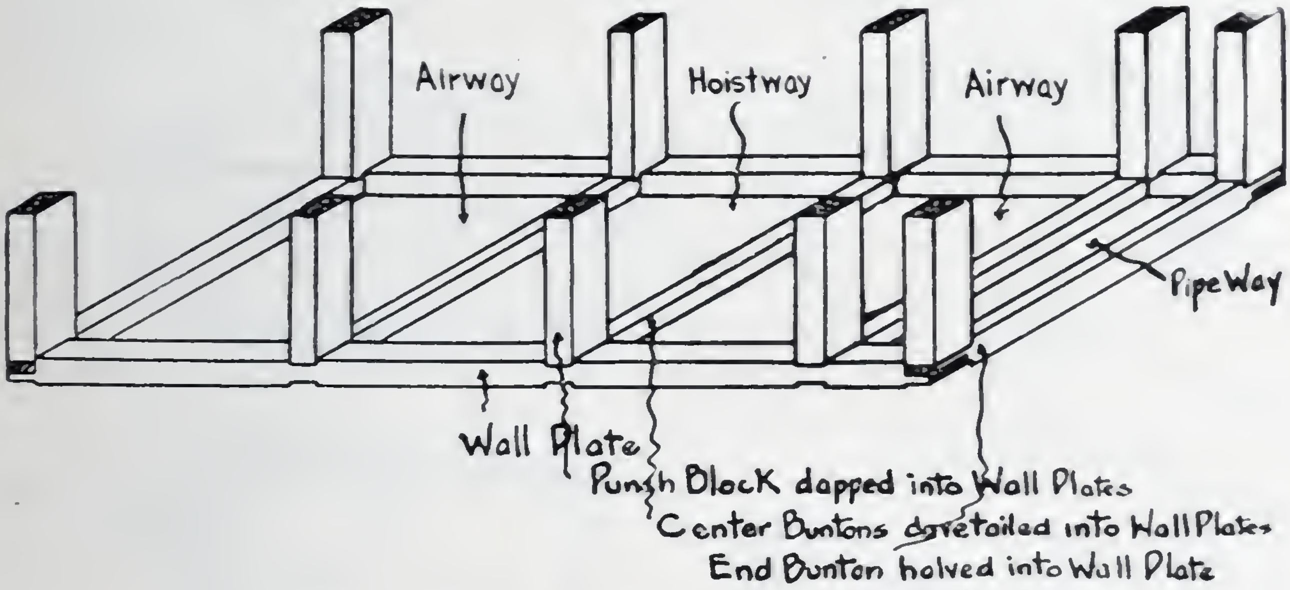

Fig. 1. Typical Timber Set.

country were timber lined (See Fig. 1). In the Middle West the timber linings were usually "skin to skin"; that is, the rings or sets of timber were placed one directly on top of the other and fastened together with drift bolts. This is an effective means of protection in soft, running and shaly ground, and most of the older shafts in Ohio and Indiana were put down with "skin timber" linings, while in Pennsylvania and West Virginia framed timber sets spaced four or five feet apart vertically with two-inch or three-inch lagging behind them were generally used. In 1903 at South Brownsville, Pa., a pair of concrete caissons were sunk for two shafts, for it is largely river silt that overlies the rock on both sides of the Monongahela River at a number of stretches just above Brownsville. After sealing the caissons in the rock, there

remained about 45 feet to the coal, and this was lined with concrete in place of the usual set timber lining. These, as far as I can find, were the first all-concrete lined shafts. In 1903 at Gary, W. Va., there were constructed two deeper shafts, elliptical in shape and lined entirely with concrete. Engineers generally were slow in accepting this new method of lining shafts, but as time went on the value of the newer designs impressed themselves on mining engineers, and to-day most of the new shafts are concrete lined, and many that were formerly timbered have been lined with concrete when relining became necessary. Some typical concrete linings are shown in Fig. 2.

Concrete lining is generally a little more expensive than timber lining, but under most conditions it is permanent. There are sections of the country where strata through which the shaft is

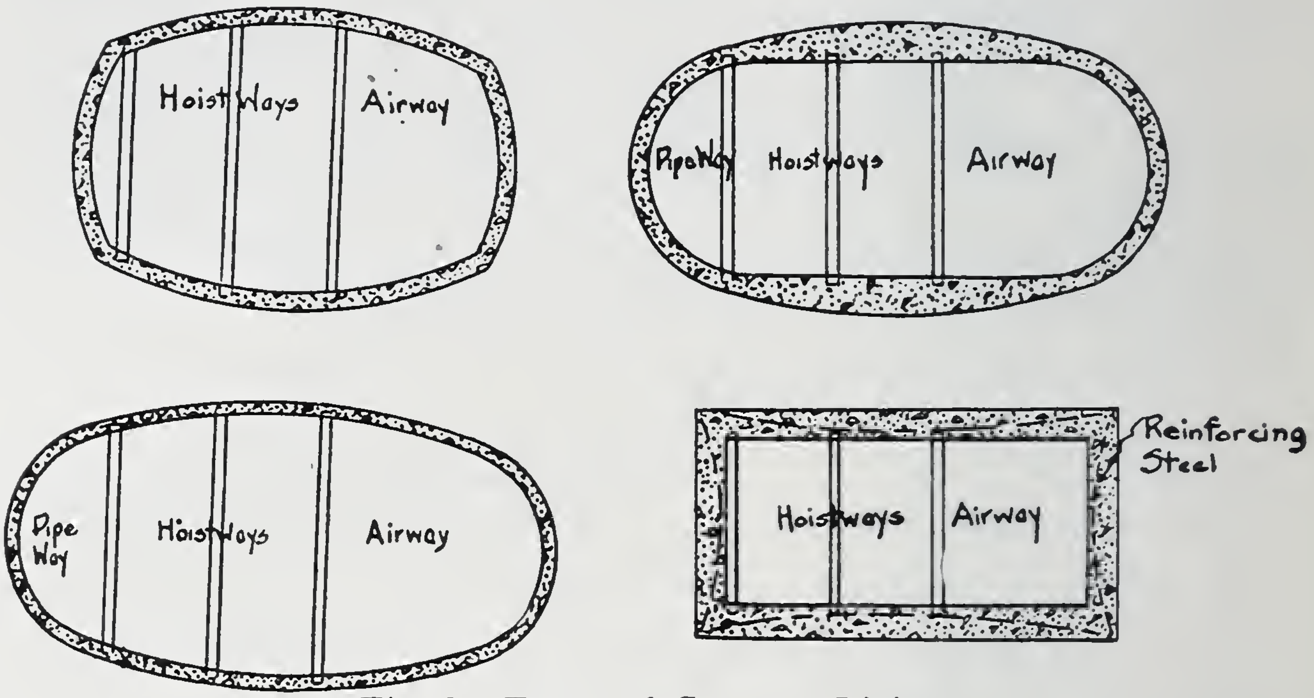

Fig. 2. Types of Concrete Lining.

sunk provide sufficient sand rock for concrete purposes and, with the present high price of timber, concrete lining can be done about as cheaply as timber lining. Concrete lining generally provides a dryer shaft, for much of the water that comes from the ribs can be plugged or grouted; this I shall discuss briefly later.

While concrete provides a stronger lining, standard 8 by 10 timbers on five-foot centers with two-inch lagging provide a lining amply stout, and with water rings which are catch-basins around the shaft just behind the lining, and proper draining, a timbered shaft can be made as dry as a concrete shaft. The question really

resolves itself into a comparison of first costs and ultimate costs. The life of a first-class lining of white oak or long-leaf yellow pine, if the shaft is dry, will run from 12 to 20 years. If the shaft is wet, with water constantly dripping over the timbers, its life with minor repairs is almost unlimited. If the field of coal is a small one with a life of 20 years or less, timbered shafts in most sections of the country are cheaper, for the moisture that is found soaking into the timbers in most timbered shafts in this section of the country provides a good fire protection and acts very effectively as a wood preservative. Only in exceptionally dry shafts is a timber lining dangerous. Timber linings in new shafts are not permitted by the state laws of Illinois because of the fire risk. The timbers in some of the later installations have been treated with wood preservatives, but this is not advisable, for it would prove a splendid fuel for a fire.

While I believe the fire risk is small, nothing should be left undone that will remove any risk to life, and this thought always uppermost in the minds of mining engineers to-day generally decides in favor of the concrete shaft.

But after 20 years of watching the developments in the design and construction of concrete-lined shafts, I am not sure they are entirely satisfactory. A large number of the downcast shafts which are lined with concrete are pock-marked. The lining is slowly scaling and disintegrating. Moisture or rain or dripping shaft water is sucked down with the incoming air and, of course, wets the surface of the lining. The concrete naturally absorbs some water and alternation of freezing and thawing eats into the lining, causing it to peel scale by scale. I am convinced that we must find a suitable waterproofing for downcast concrete-lined shafts, or we shall have to provide a veneer of some impervious nature. I believe vitrified brick would make a very effective veneer, the brick to be laid in cement and locked every four or five courses to the concrete lining with a row of headers (See Fig. 3). Of course, in constructing a plain concrete lining, it is possible with very careful puddling while the concrete is being placed to remove most of the small air bubbles, and in some linings waterproofing compounds have been used; but the success of these waterproofings has been rather indifferent. This trouble with

linings to-day is the most serious problem in good shaft construction, closely akin as it is to the handling of the water through the lining.

A treatment of a lining for a shaft in this section scaled and pock-marked by the action of water and ice has been proposed by a New York waterproofing concern, and the work, which I under-

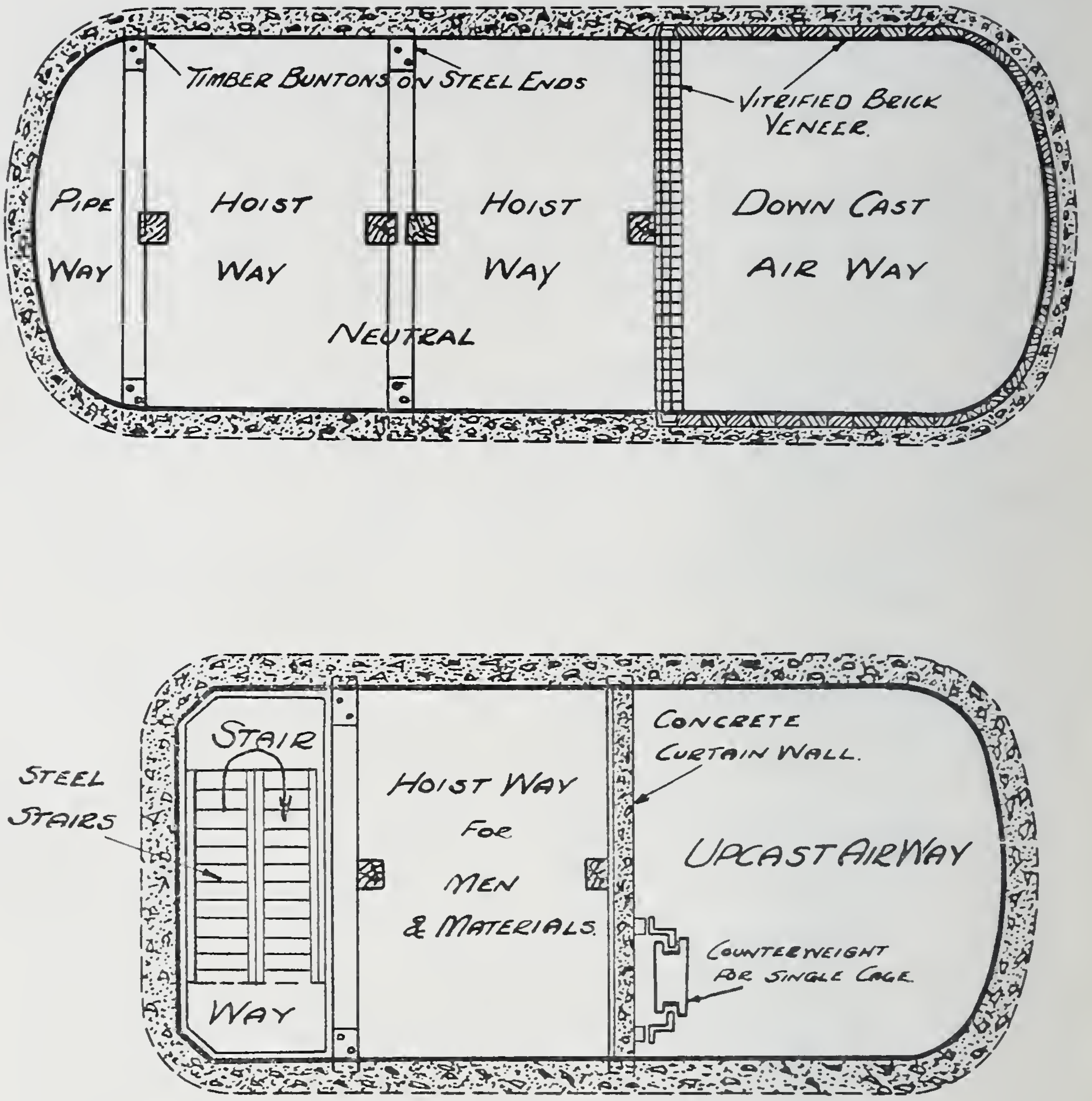

Fig. 3. Plans of Shafts Embodying Latest Practice in Design.

stand will start this spring, will certainly be watched with interest.

In England, France and Germany brick is used for most of the deep shafts that are masonry lined, but engineers in this country have never strongly inclined toward either brick or concrete block. In a flat-sided shaft, brick or block do not give the desired strength in soft strata. Concrete fulfils all requirements of

strength and will stand the unusually severe strains produced by the blasting necessary in the sinking process.

Pipes, drains, and bunton and guide connections can be placed in the lining as it is being constructed. The concrete should be mixed in the proportion of 1:2:4. It should be from 12 to 18 inches thick. Provision is always made, however, that points of solid rock may project within four or six inches of the concrete form. This unquestionably adds to the support of the lining in the shaft.

Concrete, then, will be the medium for the lining of the shafts we are designing, using a vitrified veneer for the downcast compartment, which will be separated from the hoistways by vitrified-brick walls laid in panels on the buntons.

The function of the buntons in a concrete shaft is principally to hold the guides in position. They are seldom figured to support or brace the lining except in the earth surface. This does not conform to the ideas of some, but experience has surely proved that the rock measures have no lateral movement when they are practically horizontal. Use has been made of many different sections of buntons of timber, steel, and combination steel and concrete. With timber set lining the bunton is a necessary part of the framework. Timber buntons and steel buntons have resilience to absorb and dissipate the strain imparted to them through the guides by a fast-moving cage or skip, but the only reinforced concrete buntons I have ever seen were full of small cracks caused, I assume, by vibration. The steel H-beam makes an ideal bunton for a concrete shaft. It should be placed on edge and the top concavity filled with concrete to prevent water from settling therein, but the steel bunton is not readily replaced in case of a wreck of the shaft, and many in the last few years have either used the timber bunton concreted in place or set in hitches left in the lining; or a timber bunton which is bolted to short sections of I-beam or inverted channel concreted in. The various types are shown in Fig. 4. The principal objection to steel is its susceptibility to corrosion in the combination of mine air and mine-water drippings, and, while it can easily be painted outside the shaft, nothing entirely effective can be done in the shaft on account of the dampness. The best paint for mine buntons is the home-made mixture

of coal tar, Portland cement and kerosene applied hot to the clean steel. I know of one case where the buntons were painted with this combination 10 years ago and recent investigation showed the buntons to be in fine condition. Many believe steel buntons are best, but, because they cannot be quickly replaced since they are concreted in, a large number incline toward the timber bunton bolted to short steel I-beams concreted in the lining. Where a masonry partition wall is built in the shaft steel buntons are, of course, best.

Guides for the cages are practically always of timber, a prime grade of long-leaf yellow pine being the most desirable. Steel has been tried, but I know of no successful safety device that will work on steel guides to guard the cage from falling in case of

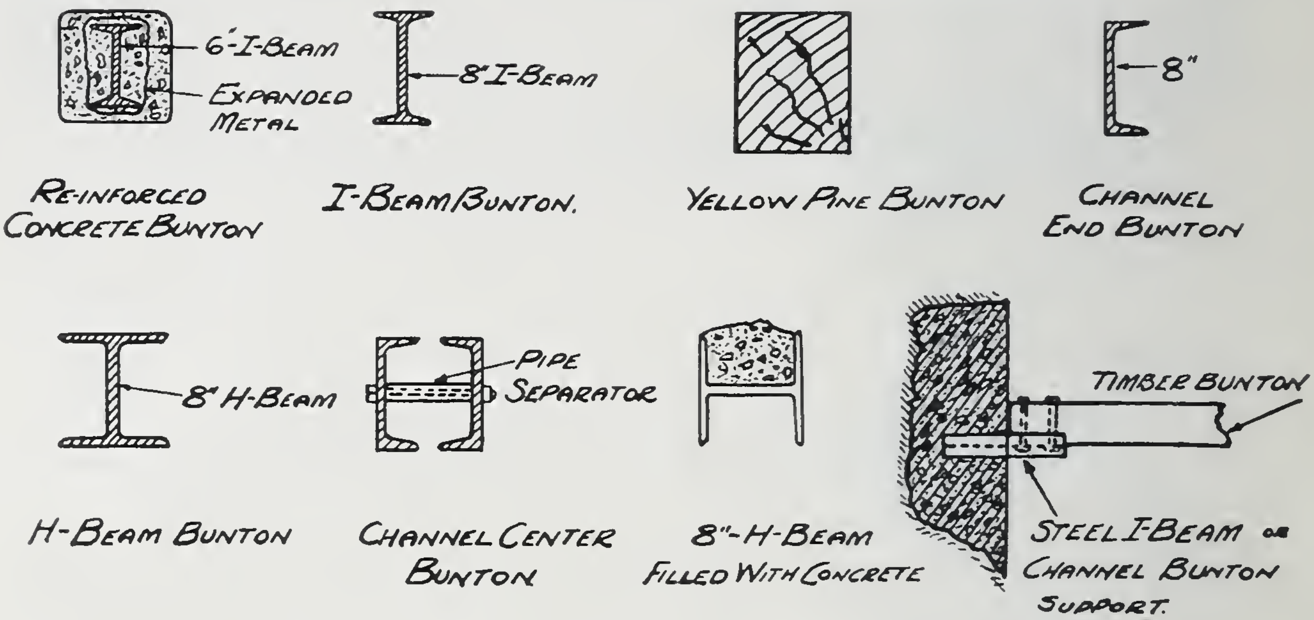

Fig. 4. Types of Buntons.

accident. Set accurately to plumb-line and gage, the guides are dapped over the buntons and bolted to them. There are several schemes of splicing the guides, and the simplest and best of these is undoubtedly the butt splice. All bolts are countersunk into the guides, and the heads of the bolts should be set in at least a quarter of an inch deeper than the face of the guides (See Fig. 5).

Partitions in timbered shafts are of yellow-pine tongued-and-grooved sheeting either of two layers of one-inch tongued-and-grooved material spiked with loose joints to the buntons, or of one layer of 1½-inch tongued-and-grooved sheeting. Partition walls, or curtain walls as they are often called, in concrete-lined shafts are nearly always of reinforced concrete, and while some have

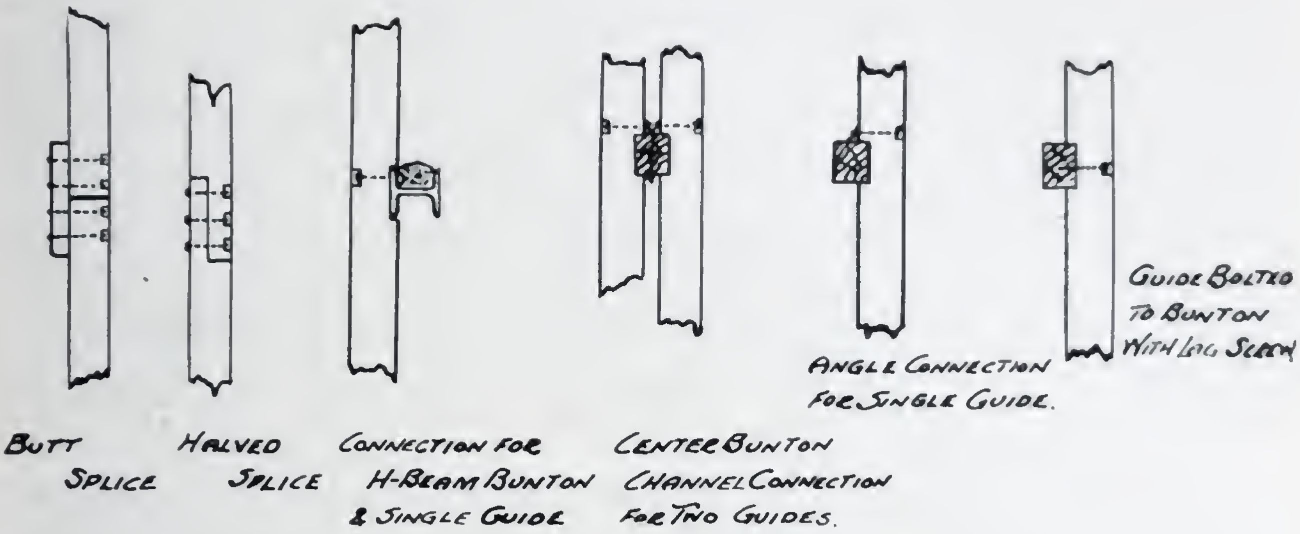

Fig. 5. Types of Guide Connections.

been constructed as a continuous solid concrete wall from top to bottom, a thinner and stronger wall can be constructed on steel buntons placed at intervals of five or six feet in the shaft. The walls are usually reinforced, and a typical design is shown in

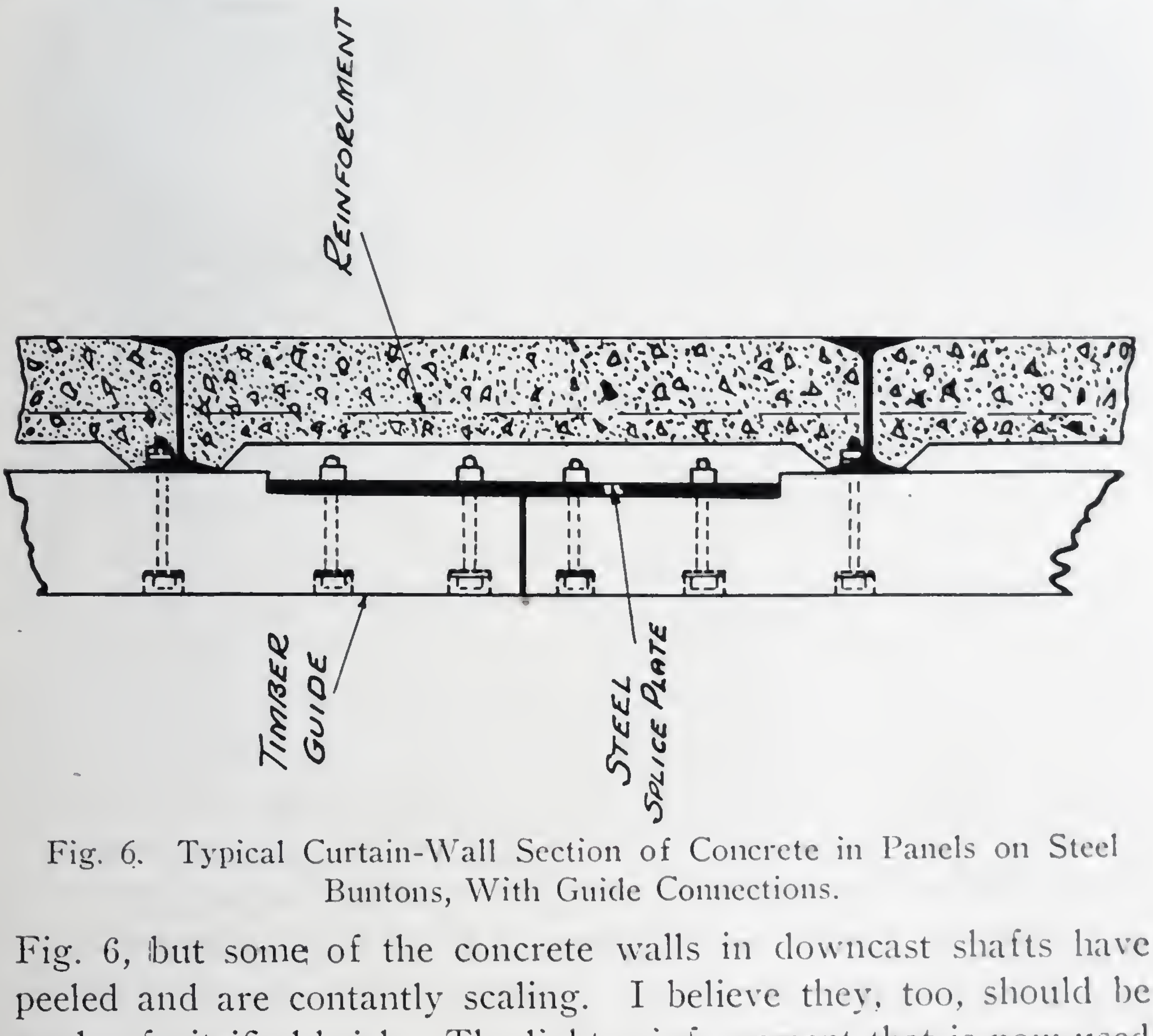

Fig. 6. Typical Curtain-Wall Section of Concrete in Panels on Steel Buntons, With Guide Connections.

Fig. 6, but some of the concrete walls in downcast shafts have peeled and are contantly scaling. I believe they, too, should be made of vitrified brick. The light reinforcement that is now used

in concrete walls can be used just as well in the brick wall. Laid in cement mortar with thin joints, they should serve their purpose well. I favor vitrified brick simply because it is the best medium that I know which presents an impervious face. If we can find a waterproof paint that can be applied so that it will be absorbed into the pores of the face of the concrete, or a waterproof plaster that will cling to the lining and will stand the test of time in its resistance to the water, our problem is solved and concrete so treated will be ideal.

The handling of water which is encountered in the sinking depends largely upon the amount of water and the nature of the rock. Grouting is the only method of preventing the water from coming into the shaft, and to-day provision for the sealing of water by injecting cement into the fissures of the water-bearing strata is a part of all specifications. To-day, all prices in contracts for sinking shafts are based on the assumption that if water is encountered grouting will be started and paid for according to provisions in the contract. Usually grouting is paid for per barrel of cement injected, but it would seem that a method fairer to both parties would be an agreement to pay for the cost of grouting on a basis of cost plus a fee per barrel, the fee to include the use of the contractor's plant, and his profit. The grouting clause and its price to-day takes the place of the water clause in the contracts of 12 and 15 years ago. This clause in former contracts provided for additional prices per vertical foot sunk in case certain quantities of water were struck, the prices to increase as the quantity increased, but this was an inequitable manner of paying for the cost. On one job I saw the contractor lose everything he had because he could not get below the water, the rock being blocky and full of fissures, so that he could make no footage at all in sinking and consequently could earn no premium to pay for the cost of his constant pumping. On another job a contractor was able to construct a water ring just below the water stratum, which was reasonably close to the top of the shaft, and placing his pumping plant at this ring he pumped on, the pumping having no effect on his sinking, which was practically dry. According to the water clause, he was paid, of course, by the foot sunk for the additional water, and he sunk well and his coffers were filled with gold and there was great joy in the house of the contractor. The fairest

water clause for pumping is the one based on paying by the million-foot-gallons for all water pumped. This form of water clause (in addition to the clause for grouting) was used in the contracts for the shafts and tunnels for the Catskill aqueduct which was completed several years ago. A typical water ring is shown in Fig. 7.

In grouting, cement mixed with water to the consistency of cream is forced into the crevices under high pressure through drill holes in the rock, or pipes through the lining. The process was used first in shaft sinking in this country about 1910 on the construction of the Catskill aqueduct, although in Germany and in Northern France the principle was used several years before in

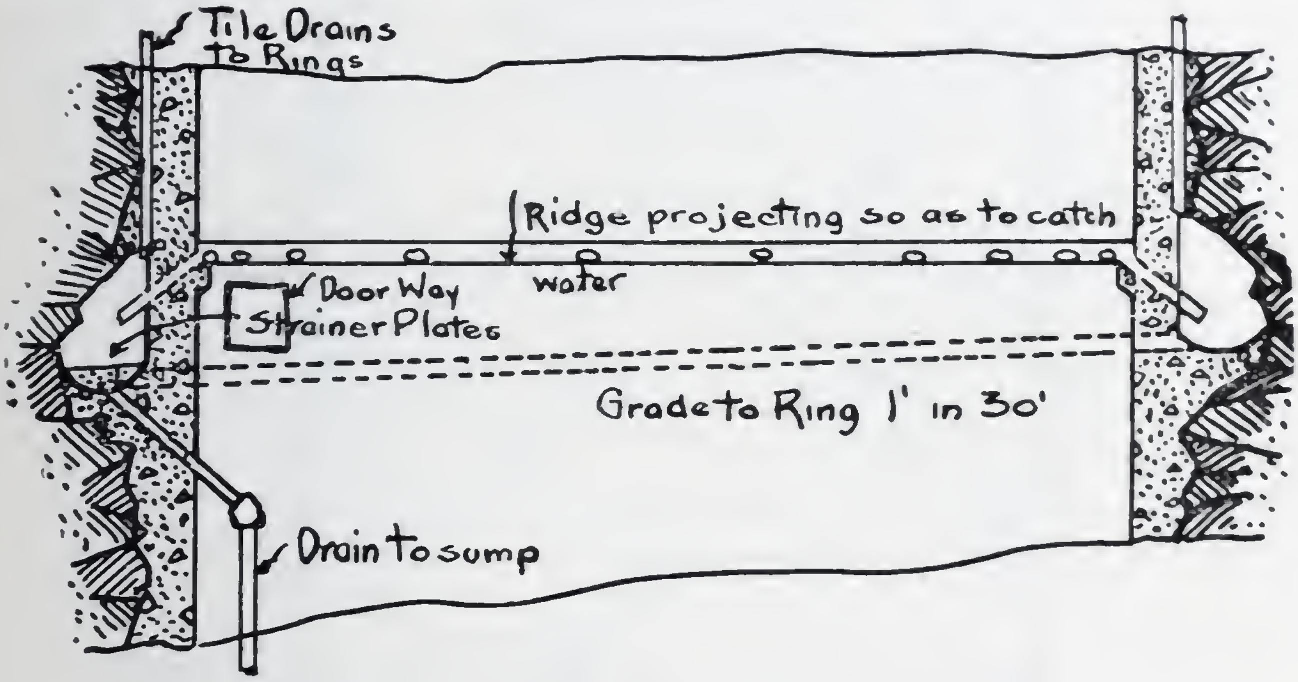

Fig. 7. Typical Ring in Concrete-Lined Shafts.

cementing around the outside of the shaft before sinking was started.

In 1912 the first shaft of the coal fields was grouted. I recall very well my talk at that time with the chief engineer of the Pittsburgh Coal Company, when with boundless (and later I have thought brainless) enthusiasm I guaranteed in the name of the company with which I was connected to seal off 90 per cent. of all water encountered in the sinking of a timbered shaft which we were to construct. The job was done and the water was shut off, but that experience (with many since) while demonstrating to mining men that it was the best known means for attacking the water problem in the sinking of shafts has shown that there are many

difficult angles to the grouting game and that it is not always possible to seal off all water. The larger the crevice and the greater the flow, the easier it is to seal the crevice. The fundamental requirement to grouting is resistance. You cannot grout a length of two-inch pipe open at both ends, but plug one end and you can pack it full of grout under pressure, and it will be solid and very dense.

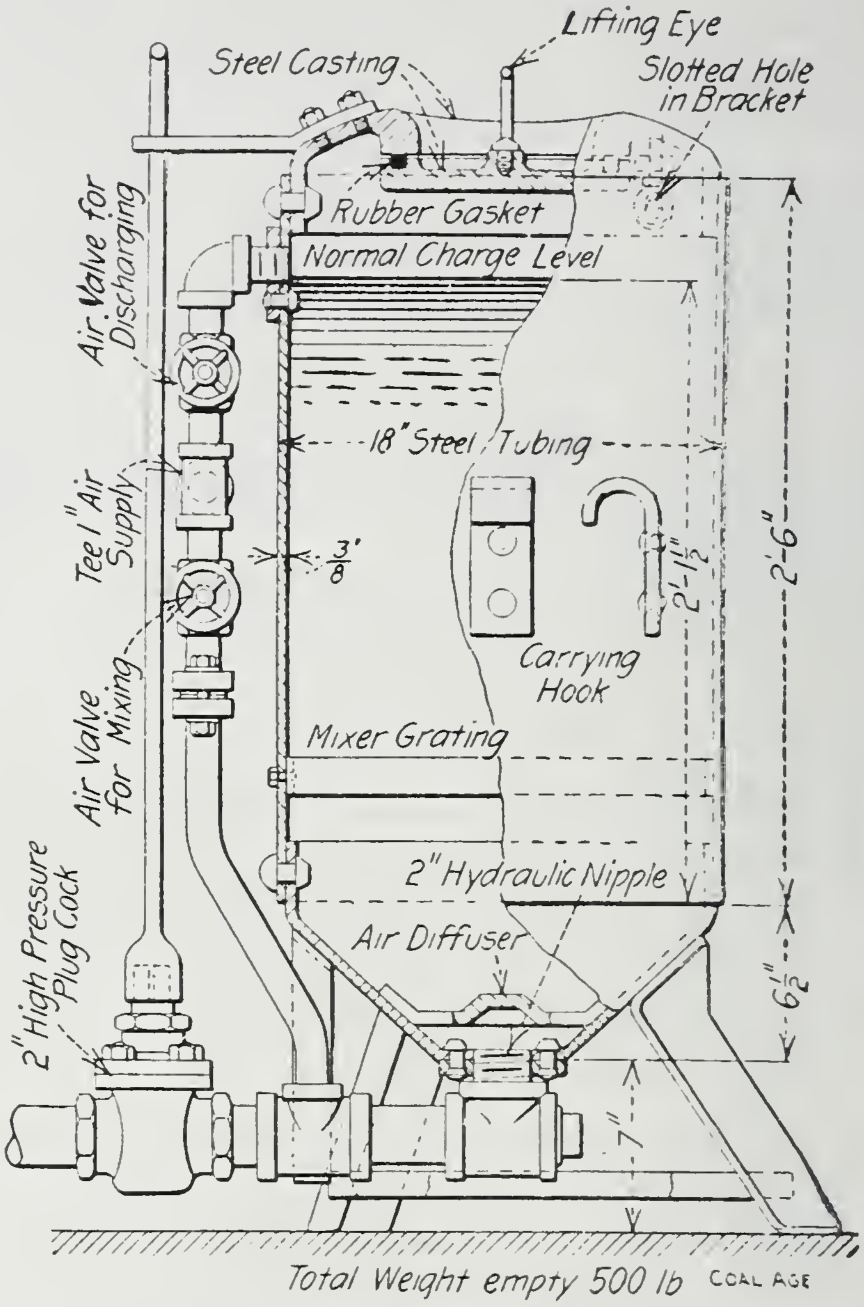

Fig. 8. Grout-Mixing Tank and Connections.

If the ground four or five feet above the stratum is solid, the grouting can be done very easily. If the strata above the water-bearing seam are full of crevices, naturally or through shattering, these cracks will allow the grout to work out because there is not enough resistance to the pressure of the grout. Such a condition will often take care of itself by the gradual setting of the thin

layers of cement in the cracks, and the forcing in of additional cement at low pressure on successive days. Often oatmeal, bran, or dry sawdust is forced in with the cement and settling in the water seals the cracks. If the cracks in the bottom of the shaft cannot be sealed in this manner, it is necessary to put a concrete mattress over the shaft bottom to provide resistance. This scheme, while expensive, has always been successful. The grout is usually

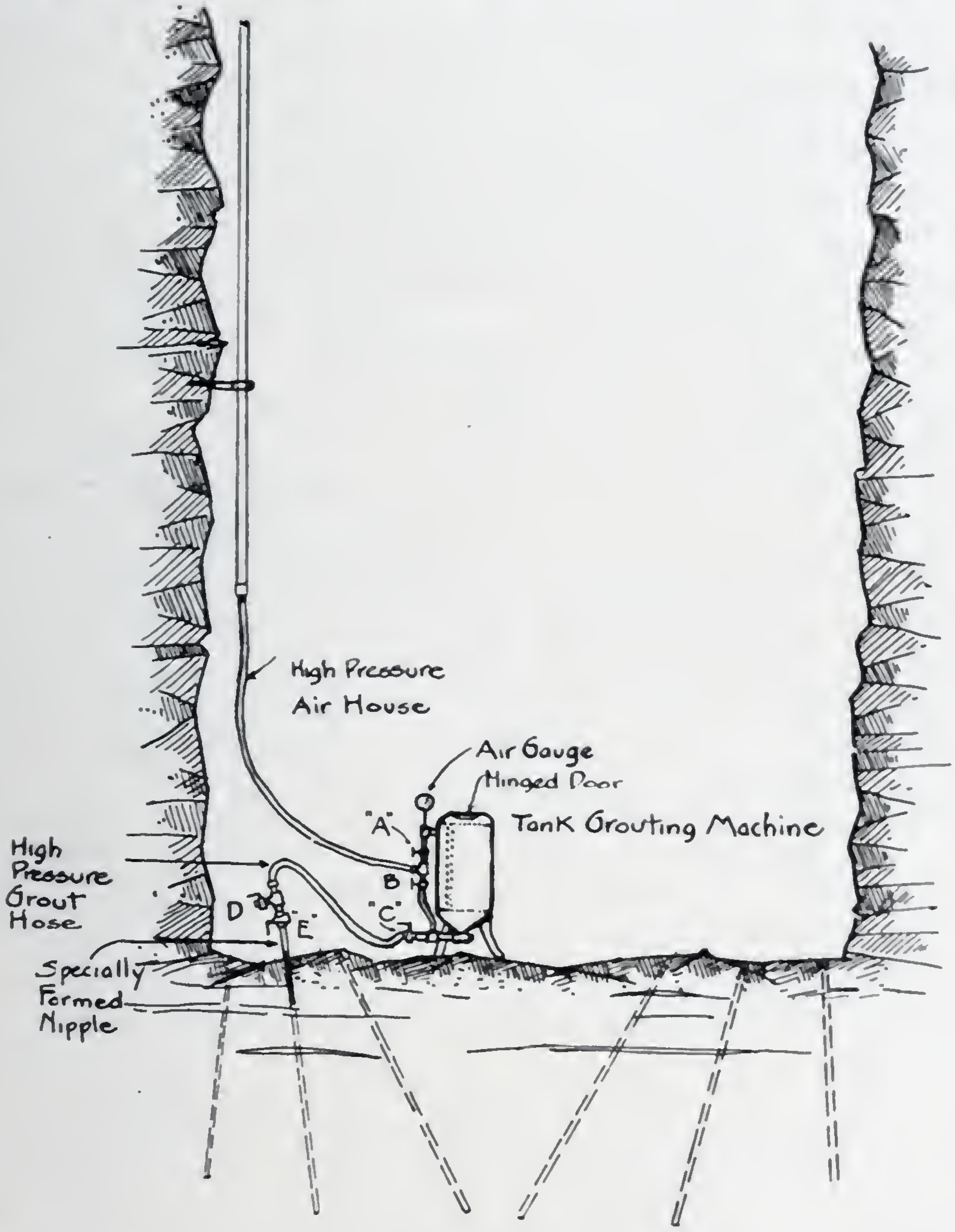

Fig. 9. General Lay-Out for Grouting Operation in Shaft Sinking.

mixed by compressed air in a grouting tank, as in Fig. 8, and forced into the crevices by turning the pressure of air in at the top of the tank; or the grout may be forced into the crevices by a pump, with equally good results. The scheme of grouting in rock in the shaft bottom is shown in Fig. 9.

The pressure used in grouting varies greatly according to

conditions. If you are grouting in solid rock, the higher the pressure the more efficient will be the grouting. Usually with a grout tank you will use up to 125 pounds pressure. If you are using a pump, the pressure available is limited, of course, by the steam pressure and the ratio of the cylinders on the pump. In several cases on the Catskill aqueduct grouting was done under pressures as high as 500 pounds, and my recollection is that in one or two cases a pressure of 600 pounds was used through the use of special equipment. Little high-pressure work is done in this section.

In grouting behind a shaft lining special care must be taken to gage the pressure properly, and definite results can never be guaranteed. If the holes to be grouted are in a round shaft, or in round ends of a long shaft, they will, of course, stand more air pressure than in the flat side of a shaft, but it is practically impossible to force grout behind a lining with less than 20 pounds of air, and the possibilities of breaking a flat lining under even 20 pounds of air are very great. When grouting behind linings was first started, pans or blisters of tin were usually put against the rock rib where the water ran out when the lining was being poured, and a hole was punched in the tin from which a pipe led to the concrete lining form, and the grout was forced through this pipe. This is still done in many cases, but if it is possible to drive a pipe into the water-bearing crevice and calk the rock seam so that all water will lead into the pipe, a much better grouting job can be done, for higher pressures can be used since there is not the area of lining over which the pressure of the grout can act.

The most successful grouting job in mine-shaft sinking was done near Welch, W Va., on the Tug River. Here a shaft that had been sunk for 10 years was still making 750 gallons of water per minute. When the mine changed hands improvements were planned and it was proposed that the shaft be lined with concrete, the lining to be designed so as to withstand pressure sufficient to grout the flow of water. We designed a heavily reinforced lining and used a very heavy H-beam section for buntons to be figured as struts. Back of the lining we placed corrugated iron, and canvas back of this, our idea being that when the grout was forced behind the lining it would fill the pores of the canvas and absolutely insure a water-tight job. When the grouting was finished,

the shaft made, as nearly as we could figure, one quart of water per minute. I may add that the success of this job is decidedly unusual. Many equally heavy streams are encountered nowadays, but they are grouted in the sinking, and the necessity for heavy linings is avoided.

Grouting in slopes is a more difficult proposition. Since the strata are usually horizontal, the grout injected into the crevices must travel over a greater area to be effective. In water-bearing country it is wise to keep a test hole ahead pointed downward at a greater angle than the angle of the slope. If water is struck, more holes are drilled and grouted to refusal, but in driving a slope through a horizontal water-bearing crevice it requires a long horizontal distance to get beyond the drainage area of that crevice, so that the sealing of water from a single crevice often requires several grouting operations. Each operation requires not only the time for the injecting of the grout, but a longer time to allow it to set before again shooting the face.

With the coal operator who is not familiar with the process of grouting the question of cost naturally arises when letting a contract. He is, of course, anxious to cut down the cost of his pumping, and any process or device which will save him dollars is interesting. Let us take a typical case. Assume the shaft to be 400 feet deep and a stream of 200 gallons per minute encountered in the sinking. If this stream is not sealed he will have to pump it throughout the life of the mine. If his power averages one cent per kilowatt-hour, it will cost him in the neighborhood of $3000 a year. On a 15 per cent. basis, it will be found that he could afford to spend $20,000 to seal off the water. While the rock in different sections of the country largely determines the grouting conditions, and hence the expense of grouting, the average cost of sealing off this quantity of water would not run over $3000 or $4000. I have been connected with jobs on which the total cost of grouting streams far in excess of 200 gallons per minute was not over $2000, and I know of no work on which a stream of this quantity has cost more than $5000. The operator could thus pay for his grouting in a year and save $3000 or $4000 a year afterwards.

Some engineers are of the opinion that in the mine development there is a possibility of catching the same water that is sealed from the shafts. There are cases where I believe this is possible, and, if the stream is directly above the coal, I can appreciate the hesitancy on the part of the engineer in his instructions to grout, although the absence of such a stream in the shaft, even though it should come out later in the mine, would be a very good thing for the shaft bottom. If the water is above a substantial streak of fire-clay or a thin vein of coal above the one being worked, I do not believe there is much likelihood of water penetrating the strata above the coal and flowing into the mine; at least until the ribs are drawn and the roof measures have sagged or fallen. Water usually flows in underground streams rather than simply lying in huge pools. It is very seldom that it is possible to pump dry a stream encountered in sinking. I am familiar with only one case where this was possible.

I have not discussed air-shafts as such, for the general details are, of course, the same as in hoist shafts. Stairs, if such are installed, are either of steel or wood. Steel makes the cleanest looking and strongest job, but a steel stairway is exceedingly difficult to paint effectively in the shaft. Yet of all details a stairway from a mine should be fireproof. In designing an air-shaft to pair with the hoist shaft which we have planned, I would include a stairway compartment, a hoistway to handle men, supplies, and cars of slate, the cage for this hoistway to be counterbalanced, and an airway for the fan to be separated from the hoistway by a masonry partition wall.

The need for air-shafts at innumerable plants situated at points back in the mine is not half realized. I venture to say that fully two-thirds of the mine owners would find a tremendous saving in power costs if they would invest in air-shafts. Pumping air long distances under heavy water gage will in most cases cost many times the interest on the capital required to put down an air-shaft. Most men would jump at the opportunity to invest in a safe 10 per cent. proposition, yet many coal operators hesitate to invest in air-shafts, even though such an investment would show a 20 or 30 per cent. return. That more attention is not given to the cost of ventilation is very strange indeed.

Shaft design and sinking in soft and running ground often require the use of caissons with the use of compressed air. In such conditions it is the most economical and in great depths the only practical method of reaching rock. The depth determines the thickness and reinforcement of the shell, at the bottom of which is usually attached a steel shoe or cutting edge. The inside dimensions of the shaft are usually 12 or 15 inches larger than the standard shaft size, and in exceptionally great depths this allowance is usually more. This is done to take care of the possibility of the caisson getting out of plumb as its sinking progresses.

As the material is removed from the inside, the shell sinks and sections are added to the top. If the quantity of water becomes too great for pumping when the material is handled by hand, or if boulders or other obstructions prevent further work with dredge buckets through the water, it is necessary to put in a diaphragm or deck and work by hand under compressed air. One of the greatest difficulties in deep caissons of the size required for shafts is the work and expense required to straighten a shaft after it has shifted out of plumb. The sealing of a caisson in rock so that the compressed air can be released and the deck removed is a most expensive and particular detail, and at great depths requiring high pressures, and consequent short expensive shifts of men, the job is particularly costly; and, while shaft caisson sinking is expensive, slope work through running ground or quicksands is practically prohibitive in cost.

There have been few changes in the last 10 years in the general scheme of shaft sinking. The procedure, as is well known, consists in drilling the rock usually with a small type of compressed-air drill with holes so placed as to shoot out a sump or cut 8 or 10 feet deep out of the bottom of the shaft; and, when this has been mucked out, to drill and shoot the remaining section of the shaft or benches in the same manner. When these benches have been completely mucked out the procedure is repeated. Care must be taken in the placing and the loading of the hole so that as little damage as possible is done to the concrete lining and buntons above. Expert rock men can very often drill and shoot without bending or breaking a bunton by gaging just the right amount of powder necessary simply to break up the particular kind of rock

in which they are working. The nature of the rock—that is, whether it will disintegrate under the action of air and water—determines the depth which can be sunk before lining is necessary, for it is of course unsafe for men to work underneath rock which will disintegrate and scale from the sides of the shaft above.

For lining purposes the contractor will carry 40 or 50 vertical feet of concrete forms, which are usually made in sections. When it is decided to concrete, the muck is leveled off in the bottom of the shaft and sections of forms, designed according to the plan of the shaft and usually five or six feet in height, are bolted together to make a complete ring. The bunton ends or buntons are placed in notches set in the forms, and the space between the rock rib and the form is filled with concrete. This process is repeated until the stretch of concrete is joined to the old concrete above. As soon as the stretch of concrete is completed, the muck in the bottom of the shaft is taken out and the concrete forms are removed, when the process of sinking is again resumed. That blasting so soon after concrete is placed does not shatter the concrete seems remarkable, but I have never seen cracks from this cause.

We cannot close any discussion of shaft design and sinking without giving a few words to slopes, for in the last few years and at the present time they are being very favorably considered for coal under 200 feet in depth both for haulage and for manways. Conveyors, both of the rubber-belt and steel-apron type, have been very successful in moving big tonnages at a low cost. For rubber belts a slope with a maximum of 33 degrees has been used, but I have heard users of the 30-degree slope say that they are too steep. Slopes for manways and supplies are usually sunk on a 25 per cent. grade. Slope linings of concrete depend upon the roof's span for their design. Openings over 15 or 16 feet wide are expensive to construct in localities where there is soft rock or unusual depth of earth over the rock. Any slope is difficult to sink in soft earth and extravagantly expensive in running ground, as has been noted. In ordinary earth it costs about twice as much per lineal foot to sink as in solid rock because the earth is harder to remove than blasted rock, and timbering with sets closely spaced is required to prevent the roof and sides from caving.

In order to overcome the difficult construction of a very wide slope in localities where there is excessive earth or soft rock, two companies in this field have constructed double-deck slopes similar in design to Fig. 10. While expensive to build, one such slope is cheaper than two slopes having the same capacity, or than one slope of the same area with the compartments side by side. Practically all concrete-lined slopes to-day have arched roofs from 12 to 18 inches thick. The side walls should be 12 to 15 inches thick. Arched slopes are naturally the strongest and do not as a rule require reinforcement. The additional area in a slope with an

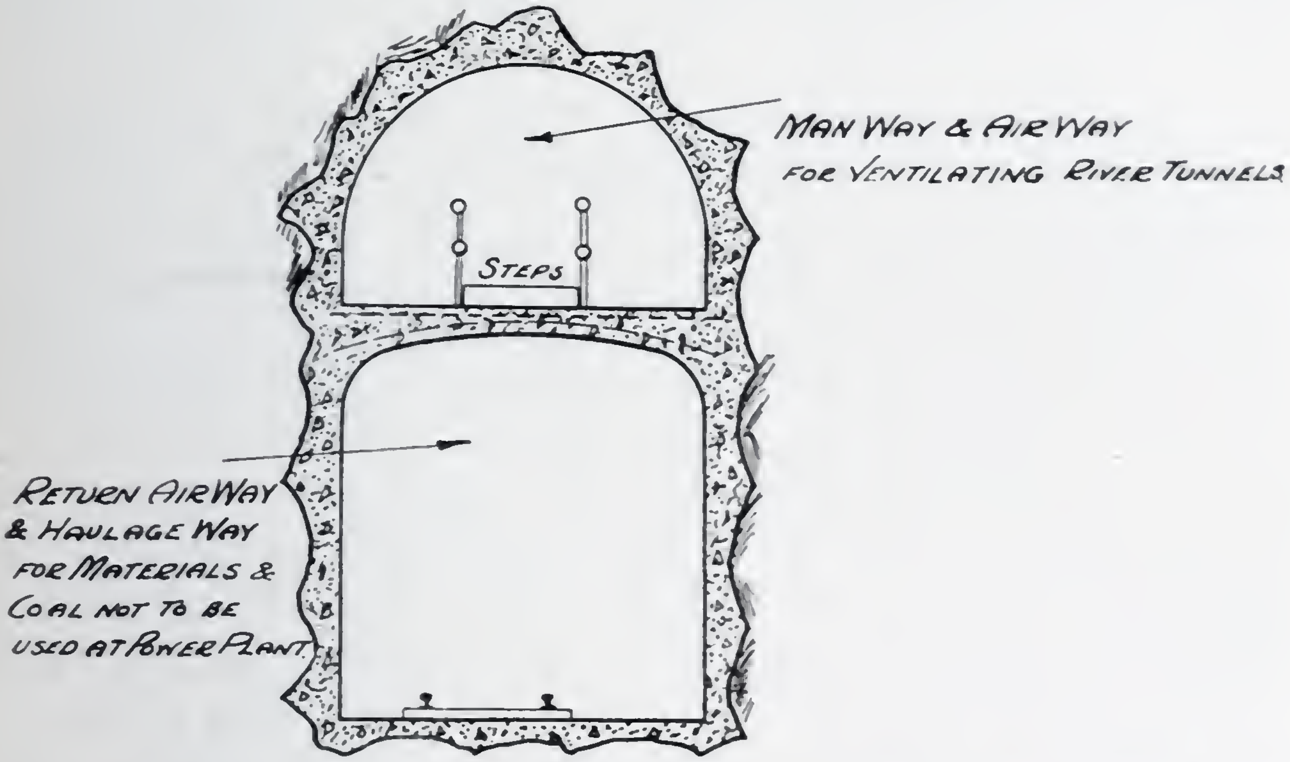

Fig. 10. Double-Deck Slope for Springdale Mine, West Penn Power Company, Logans Ferry, Pa.

arched concrete roof over the area provided by a rectangular section is always to be desired for ventilation and head room.

DISCUSSION

Mr. H. N. Eavenson:* I might mention an instance illustrating the grouting process in a shaft below Welch, W. Va., sunk within the last two or three years. An old shaft had been in operation for probably 8 or 10 years and always had a lot of water; I think they estimated about 1500 gallons a minute. This shaft was sunk a great many years ago and was not grouted at the time. When a new shaft was started, a little over a half mile above the old one, they began to grout it. They were possibly 1500 to 1800 feet from the new shaft. They eventually made a fairly tight job of it. I know of another case of a shaft being sunk there now. Two had been sunk along one of those narrow mountain valleys, I think about 1911, and they were both grouted. The third shaft is being sunk now for an additional airway, not over 100 yards from the old air-shaft. There was a six-inch hole drilled down to the mine to drain the water which was to be pumped up by the old equipment with a pump of 1000 gallons per minute capacity, in addition to what they had. The shaft was only down about 50 or 60 feet when they encountered so much water they could not take care of it and they had to seal that hole off and fill it with concrete and begin to grout the new shaft. They told me they estimated they were getting a flow of 3000 gallons a minute, but the engineer in charge did not see how they could get that much through a six-inch hole. Anyhow, it gave them so much trouble that they plugged the hole. They are also sinking three more shafts, and that is a point that came to my mind when Mr. Johnson was speaking of airways. The plants are designed so that the first 100,000 feet of air will give them not to exceed 0.25 inch water gage. That is far in advance of anything else I know of in the country. They have a shaft now where they had 0.3 inch for the first 100,000 feet, and the usual pressure is very much greater than that.

I was very much interested in the suggestion of putting a brick lining in the shaft, but it seems rather expensive. Have you any figures?

*Howard N. Eavenson and Associates, Pittsburgh.

MR. R. G. JOHNSON: No, I have not; but I can get you some.

MR. H. N. EAVENSON: It occurred to me that you could get a vitrified sewer pipe or building block at very much less expense.

MR. R. G. JOHNSON: You would have to back up the lining with concrete because the soft strata will disintegrate behind the block. There have been tunnels lined with a concrete block which have proved very successful, but I do not know just how it would work in a shaft where a disintegrating stratum would constantly fall. The water would back up behind and gradually seep through almost any kind of lining.

MR. E. T. GOTT:* Water comes through the concrete, and in my opinion that is what is doing the damage. It is not the water that falls down in the shaft; it is that which comes through the concrete that makes the concrete inert. I believe if you have any flow through the lining, it will weaken the lining and eventually break it down.

MR. R. G. JOHNSON: I had an experience along this line several years ago. We were grouting a shaft up above Johnstown and there was about 60 feet of water in the bottom of the shaft when we were attempting to grout the lining 100 feet up from the bottom. In the process of grouting an overflow of the charge goes into the shaft when you open your release valve. When we went to the bottom we found that 40 feet of the shaft was apparently filled with cement. If we had put all the cement used in the grouting down in the bottom without putting any of it in the holes it would only have filled up about 10 feet. That was an unusual condition. I was very much interested in the matter, so I went to Dr. Bates, of the Bureau of Standards in Pittsburgh, and asked him what he thought might be the possible explanation of this. He said he would like to show me some samples he had in his laboratory. In a chemist's bottle was a lump of cement as big as a man's fist. He said a month ago that was a cubic centimeter of cement, and told me that cement has the capacity of absorbing

*Vice-President, Dravo Contracting Co., Pittsburgh.

many times its volume of water. Dr. Bates said that Professor Alfred, of the University of Wisconsin, had made a study of cement absorption and had written several papers on the subject. He explained that that was the reason why water coming through a lining constantly disintegrates the concrete around it. It takes a little bit of cement each time and gradually works in and eats the lining away. Thus the only way to prevent the water coming in contact with the cement (no matter how small the trickle is that comes into the shaft) is to put in pipe and get the water to come in through that pipe.

Mr. E. T. Gott: It is a very serious thing and it may undo much that has been developed in the way of concrete linings unless something is done to counteract it. Consider a combination shaft having a partition wall at its center. In many instances the downcast side is gone, while the upcast side is in perfect condition, both having the same amount of water coming through the lining and both under exactly the same conditions except as to temperature. In the upcast end you have moderate air, but on the downcast side you have constant freezing and thawing. We have relined 8 or 10 shafts, and those that had water coming through the lining showed signs of deterioration. I did not see cement on the face of the lining. That had washed out. It was absolutely inert—no life to it at all.

Mr. F. A. McDonald:* It seems to me that, if we want to preserve the shell, the problem is to keep the water away from it. The shell should be simply a finish to keep the air away from the rock, and the way I accomplished that in several cases was to drill holes around the outside of the shell, when there was not enough water to be a burden in throwing it out with pumps, so that there would not be any pressure behind the shell. In that way we do not have very much trouble with concrete lining.

Mr. H. N. Eavenson: It does not seem probable that the concrete lining would last over 10 or 15 years in a case of that kind.

*Chief Engineer and General Superintendent, National Mining Co., Morgan, Pa.

Mr. E. T. Gott: In the southern Illinois field I know of two cases where there is practically no water, yet the downcast linings are gone. Gunite was used to replace the disintegrated surface, but I do not know how it will stick.

Mr. H. N. Eavenson: I do not think any of the shafts in southern West Virginia have had that experience yet. There are not many there, they are comparatively new, and the climate is not as severe as it is here.

Mr. J. R. Elliott:* The author's excellent paper will be welcomed by all those engaged in the economical sinking of shafts. In regard to the disintegration of concrete lining for shafts, it seems to me that a great deal depends upon the quality of cement used and the method of mixing and placing. I have noticed concrete work done on bridges on some of the railroads around this section about 20 years ago has practically gone to pieces, which may be due to the quality of the cement or mixture used. Speaking about water, I was informed by a reputable party a short time ago that, in grouting a shaft being sunk in West Virginia, oats were put in the grout and the oats appeared in a spring located some two or three miles away from the site of the work.

Mr. J. O. Durkee:† In No. 1 Crucible shaft we had a lot of trouble with water. We began to drill holes through the walls, but, after the first experience, we actually followed with the drill holes and stuck the pipe into the drill hole 16 feet, concreted the pipe with the tank, and shot the cement in under 125 pounds pressure. When we began we blew up bubbles in the Monongahela River, but could not get the cement to stay. With a mixture of the consistency of cream it was forced back out. As we could not do anything with the cement alone, we began to shoot in sawdust with the cement, and it had a good effect. It is pretty hard to tell what the proportion of sawdust was. We put it in just as we thought it should be done. We used about eight carloads of cement in No. 1 Crucible shaft. Afterwards we went back to

*Baton & Elliott, Pittsburgh.
†Mining Engineer, Pittsburgh.

No. 2 and No. 3 shafts and used the grouting process. So far as I know those linings are intact. I was there about three years ago and the shafts were good and almost perfectly dry.

MR. E. T. GOTT: We have a job out in Detroit now where the shaft is 1160 feet deep. The history of the old job has been written and we know where to look for water. There was an overburden of 88 feet of water-bearing sand and gravel. Seams of water were encountered just below the rock at 90 feet, and others at 135, 158, 165 and 192 feet. Holes were drilled around the outside of the shaft to this 192-foot level. They are now down about 188 feet and, in sinking, it was found that all of these water-bearing measures had been thoroughly grouted by the use of those outside holes, so that in going through these measures we got no water at all. Yet the history of the old job spoke of the "millions" of gallons in the four or five seams that we have just passed through.

MR. H. N. EAVENSON: In the shaft at Welch which I mentioned they had drillings all around at intervals of about four feet and grouted those holes and did not have any great amount of water there. Then they started to drill a hole inside between two of the others, and when they got down five or six feet the water came in so fast they lost the whole shaft. They had a hard job getting men or tools or anything else out of it. It was a very unusual condition, but it did happen in that case.

A GENERAL PLAN FOR INCREASING THE CAPACITY OF THE RAILROAD SYSTEMS IN THE PITTSBURGH DISTRICT

By George S. Davison* and N. W. Storer†

Your Program Committee has requested us to predict the volume of the future railroad traffic in the Pittsburgh district, and, if in our opinion additional facilities are needed to take care of it, to suggest plans with reference to such increased facilities.

The writer's earliest recollection of the local railroad situation is quite vivid even after the lapse of years. There were four railroad lines then accommodating six railroads operating into the city, and another being completed. The Pennsylvania Central, so-called, was a double-track line to Philadelphia. Passengers and freight over this line to New York went by the Allentown route, leaving the main line at Harrisburg. The Pittsburgh, Fort Wayne & Chicago was a single-track line to Chicago, with a double track for some thirty or forty miles out of this city. The Cleveland & Pittsburgh Railroad and the Erie & Pittsburgh were operated as independent lines and used the Fort Wayne entry into the city. My first railroad journey of any importance was to Canada by way of Erie and Buffalo in 1867, with a change of cars at the points mentioned. This was the only route to Buffalo in those days. It was a 10-hour journey to the latter city, and one met very few travelers on the way. The passenger trains of the aforesaid railroads entered the Union Station as they do now. A single track leading west from the Union Station crossed Penn Avenue and Liberty Avenue at grade and by a curve so sharp that road engines were permitted around it only running light. Imagine, if you can, all the freight and passenger trains of the Northwest System passing around that curve hauled by shifting locomotives that appear, in retrospect, of a size as big as a watch charm. Then there was the Allegheny Valley Railroad operating to Kittanning, a distance of 44 miles from the corner of Pike and Canal Streets, the latter now known as Eleventh Street. No road engine could operate

*President, Gulf Refining Co., Pittsburgh.

†General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

south of Eighteenth Street on this road. We witnessed with much boyish enthusiasm the first passenger train over that line leaving this city for that land of wonderful tales, the oil region of Pennsylvania.

In those early days of which we speak, the Pennsylvania Canal was still in operation along the right bank of the Allegheny River. Then there was the Pittsburgh & Connellsville Railroad, now the main artery of the Baltimore & Ohio local system. We can remember that it operated at least as far as McKeesport, as we made a trip there one day. The train service was so slow and scant that it required six hours to make the round trip. We have no knowledge of when this line reached as far east as Connellsville. And lastly there was the Pan Handle Railroad, the one referred to above as just having been constructed. It was a single-track line, with its substructure over the deeper ravines resting upon timber trestles. During the earlier years of its existence its rolling-stock was frequently rebelling against the character of its road-bed and occasionally going off upon its own hook. Our earliest recollection of this line was seeing the wreck of a whole freight train lying in the bottom of Cork Run, and at the foot of a very high trestle that it had well nigh demolished.

In the matter of water transportation of those days, it was relatively much greater with respect to rail transportation than in these days. Stern-wheel packets served the Allegheny Valley to Oil City. While at this date we could hardly realize the extent of the traffic of that day, yet we have been informed that as many as 25 steamboats a day left Pittsburgh for the oil regions. All the pine, hemlock and oak lumber used in Pittsburgh, and for a great distance down the Ohio, was rafted down from the tributaries of the Allegheny. After a spring freshet we have seen these lumber rafts tied up in such large areas on both sides of the river in the reaches of still water that there was scarcely 100 feet of the stream left for navigable purposes. There was still some freight business being done upon the western end of the Pennsylvania State Canal. Side-wheel packets ran twice a day upon good schedule time as far as Morgantown on the Monongahela. Large stern-wheel boats carrying miscellaneous freight, and with splendid passenger accommodations, served the river towns between Pittsburgh and Cincin-

nati fully three times a week, and at longer intervals trips were made to Louisville and St. Louis, and at times to New Orleans. The most important business done by water was the coal business. In those times the lower Mississippi River Valley depended upon Pittsburgh for fuel. We cannot recall a more imposing sight within our experience than the down-river departure of the Pittsburgh coal fleet on a rise of water sufficient to permit of it, and particularly if such a rise held up long enough so that the entire harbor could be at once emptied of every barge and steamboat. Whistles blowing, the big stern wheels revolving slowly but majestically, captains bawling out their orders, deck-hands here, there and everywhere—now casting off hawser, then making a cable taut; the wharves crowded with interested spectators, particularly the relatives of the inland mariners, everybody waving good-byes with much hilarity, but often mingled with tears. And a few weeks later the local banks were bulging with the returns from delivering the coal at the lower ports. In the period immediately after the Civil War we are informed that fully 80 steamers were engaged in this down-river coal traffic, in addition to the job boats plying in and about this harbor.

Those were the days of the coal barons, the iron masters, the glass men and the steamboat owners of Pittsburgh. Their names spelled aristocracy, but every one of these captains of industry was on speaking terms with all of his employees.

Fifty years ago a passenger out of Pittsburgh headed for Philadelphia and New York had the choice of three daily trains within 24 hours. As for the speed of these trains, it might be realized when it is known that the fourth through train—and, by the way, the fastest train between Pittsburgh and New York—was added in 1874 to the service on the Pennsylvania, and made the run in a little less than 14 hours. What purported to be a daylight service west on the Pennsylvania left New York in the morning and by midnight pulled into the Union Station, on about a 15-hour running schedule. In those early days there were two trains a day to Cleveland, Cincinnati, and St. Louis, and through to Chicago; and four, by two lines, to Washington and Baltimore. There was a train to Buffalo, all daylight, with a change of cars at Erie. There was no direct rail line to Wheeling. Without

exception all mail and express matter was carried on regular passenger trains. Sleeping cars were comparatively few and patronized only by the rich.

A great impetus was given the passenger service in 1876 due to the Centennial Exhibition in Philadelphia. The traveling experience of the public in that year appeared to inoculate the people with a keen desire to travel, which it appears to be difficult to satisfy. In anticipation of the increased traffic that would be handled that year, both the Baltimore & Ohio and the Pennsylvania System added much to their main-line trackage and their equipment, and established new trains and shorter running schedules, a considerable portion of the latter being found to be permanently necessary.

For comparison of the passenger service of the former times just mentioned and that of to-day, here are some facts with respect to the latter. The daily service of through trains by local lines is as follows:

To	Number of Trains
New York	18
Philadelphia	23*
Baltimore and Washington	10*
Buffalo	8
Cleveland	15*
Wheeling	11
Cincinnati	6*
St. Louis	7*
Chicago	14

*Some included in other lists.

In addition there are trains for mail and for express exclusively. On the Pennsylvania Lines East alone there are seven mail and express trains running each way.

In the early days of our recollection there were about half a dozen oil refineries on the left and one on the right bank of the Allegheny River between Forty-first Street and the Butler Street bridge, then known as the Sharpsburg bridge. They could all have been placed upon a hundred-acre lot. There are single refinery operations of to-day covering areas of one thousand acres.

The Penn, the Hope and the Banner cotton mills, each of considerable importance, were in operation in Alleghenytown between Federal and Anderson Streets. Glass plants for making bottles, tableware and window-glass were very numerous throughout Birmingham (now South Side), and Bayardstown and Lawrenceville on the Allegheny River.

The only blast-furnace we can recollect was the Shoenberger furnace at Fifteenth Street and the Allegheny River, although there were undoubtedly several more at different points on the lower Monongahela in the West End and at Woods Run. Crucible steel was made at two plants along the Allegheny River. Bessemer steel had not yet been made in Pittsburgh, the first Bessemer-process plant in this vicinity, as we recollect, being the Edgar Thomson, built in the early '70s. There was a rolling-mill on Main Street, Sharpsburg, on the site of the present Moorhead mill, and another at Millvale. With the exception of these and a couple of mills at McKeesport, one making finished iron, all the rolling-mills were to be found on the left bank of the Allegheny between Eleventh and Thirty-third Streets, and above the Pan Handle Railroad bridge on both sides of the Monongahela; in the West End and Lower Allegheny on the Ohio. There was one mill on the Allegheny and one on the Monongahela rolling copper plates and rods. We recall the beginning of the first bridge works in Pittsburgh. It was a small establishment on the Allegheny at Twenty-eighth Street, and was built by those pioneers in bridge designs of yore, Messrs. Piper & Shiffler. This plant was afterwards removed to Lawrenceville and became the Keystone Bridge Works, the forerunner of the American Bridge Company's plant at Ambridge.

At that time the boundary lines of Pittsburgh lay wholly between the Allegheny and Monongahela Rivers, the eastern line being at Thirty-third Street, then called Boundary Street, on the Allegheny River side, and its southern line reached the Monongahela River about Soho. The city's water supply was taken from the Allegheny River about Twelfth Street, pumped to a reservoir on Bedford Avenue, immediately adjoining the Central High School property, with a reservoir higher up the hill for high

service. Lighting was by artificial gas, made a short distance above Lock No. 1 on the Monongahela.

We hope that from the above recollections you can visualize what the Smoky City was shortly after the Civil War. Picture to yourselves what her mining and manufacturing enterprises were as to capacity and what tonnage her railroads were required to handle, and then make a comparison of the capacity in terms of main tracks and locomotive traction of the railroads of to-day with those of those former years. In a somewhat chronological order, see to what number the main tracks leading out of the Pittsburgh district have increased.

The Pennsylvania main line east is a four-track line. The Allegheny Valley Railroad was extended to Oil City and double tracked and forms a through connection to Buffalo. The Pan Handle Railroad has been double tracked substantially to Wheeling, Cincinnati, and St. Louis, with connections to the northwest. The West Penn Division of the Pennsylvania has been built, in its entirety, to a connection with the main line beyond Bolivar. The Monongahela Division of the same system has been constructed as a double-track line to Brownsville, with important connections beyond. The South West Penn Division and Redstone Branch have been built through the heart of the Connellsville coke region. The Pittsburgh & Connellsville has become one of the main arteries of the Baltimore & Ohio Railroad, and is now a double-track through line to Washington, Baltimore and points east. The Pittsburgh & Lake Erie Railroad has been constructed as a four-track line north of Pittsburgh, connecting with important lines east, north and west. The Pittsburgh, McKeesport & Youghiogheny is a double-track line to Connellsville, and, with the Western Maryland, forms a main through line to the east. The McKeesport & Belle Vernon occupies the right bank of the Monongahela to Brownsville, connecting with points beyond. The last two roads mentioned are parts of the Pittsburgh & Lake Erie. The Baltimore & Ohio Railroad has built to Wheeling, and from there its lines extend down the Ohio to Kenova, with connections beyond. That company has acquired by lease, purchase and construction a double-track line to Painesville, Cleveland and Chicago. The Buffalo, Rochester & Pittsburgh has been built from Butler north-

ward and, with the Baltimore & Ohio, constitutes a through line to Buffalo and Rochester. The Bessemer & Lake Erie Railroad has been constructed as a double-track line directly northward to Lake Erie ports. The Wabash Railway has entered the heart of the city from the north and west, and this line is now known as the Pittsburgh & West Virginia Railway, connecting, at or near the Ohio River, for Wheeling, Cleveland and to the far West.

The above are the lines that, with their own rails and by connections with other lines, give both through passenger and freight service to points for at least one hundred and fifty miles.

At the earliest time of which I speak the number of main tracks of at least one hundred miles in length extending out of Pittsburgh were six in number:

Two main tracks to the east.
One main track to the west.
Two main tracks to the north.
One main track to the southwest.

To-day, should we estimate the number of main tracks leading out of the same district, counting a track but once without regard to the many points to which it may lead, we find a total of 29 tracks, or nearly seven times the former number.

The ratio of increase of main tracks is actually greater, as such lines as the McKeesport & Belle Vernon, the Monongahela Division of the Pennsylvania, the Chartiers Branch of the Pan Handle, the Pittsburgh, Chartiers & Youghiogheny Railroad, the West Side Belt Railroad and the Montour Railroad are not included, as they may be considered as feeders for the other lines that are included. Nor are the Buffalo, Rochester & Pittsburgh Railroad or the Pennsylvania lines to Cleveland and Erie counted, as they enter the district over the tracks of other lines. Considering the conservatism of our estimate, we believe we are justified in setting the ratio between the former and present conditions at seven times.

The tractive power of road engines also has increased in the same period. We do not have at hand the data to indicate the weight on the driving-wheels of a standard design of locomotive, but judging from our personal knowledge at a time 15 years later than the time we are considering, and allowing for a reasonable

increase from the earlier to the later time, we believe that the road engines on the Pennsylvania Lines East carried about 60,000 pounds upon their drivers. The heaviest type of road engine upon that line to-day carries 350,000 pounds. Taking the conservative view that the locomotive of the earlier period may have been more uniform as to weight on drivers than the locomotives to-day, we believe that locomotive unit capacity has increased fully five times. To make a comparison of the maximum capacity of the railroad lines of then and now, we multiply the ratio of increase of tracks by the ratio of the increase of locomotive effort, giving no effect to the double-header practice, and assuming the interval of time between trains; or, in other words, the trains per unit of time, being the same in both cases. We admit that the proceeding may produce but a rough approximation to the truth, and believe that the result will be much less than the fact, but such a result is startling enough for our purpose. The increase in capacity of our railroads is 35 times in a space of about 50 years. Is there anyone to be found who believes that the Pittsburgh District will stand still as a tonnage producer in the future? We can safely assume that it will increase, and, without predicting that the future will see the same rate of increase as the past, we know that such increase as will obtain must be reckoned with in all seriousness.

Having convinced ourselves (and that without referring to tonnage statistics of the past) that additional facilities for handling railroad traffic must be had at some time in the future, we should inquire as to what surplus capacity exists at this time, upon which we may draw and which we may exhaust before additional facilities need be provided. In approaching this question, we recall that during the past 40 years much has been done to increase the capacity of the existing lines in the way of adding main tracks and constructing sidings and terminal yards. As new openings in the local coal fields were made, tracks were extended to them and, as old industrial plants were extended and new ones constructed, additional facilities were provided to handle the increased tonnage produced through these improvements. All this with respect to freight business. The increase for handling passenger, mail and express business is scarcely less startling than what has been done for the freight business.

In addition to increasing the capacity of original tracks as already recounted, at least one system—that of the Pennsylvania—has constructed cut-offs for the purpose of diverting traffic from tracks that were becoming congested to tracks that could relieve this congestion. Such changes have not reduced the traffic within the district, and therefore the effect has been of a purely local character. These changes will be stated somewhat in their chronological order.

As previously stated, at one time all the traffic of every description between the lines east and the Fort Wayne System crossed Penn Avenue and went through the Union Station. This was also true of the traffic to and from the Pan Handle System. When the relations between the Pennsylvania and the Allegheny Valley became very close, both passenger and freight traffic that formerly went by way of Pike Street to Eleventh Street was thrown over into the Pennsylvania yards and station by Twenty-eighth Street. When the Monongahela Division was built up the Monongahela River, all of its traffic, except what went and came by the Pan Handle, was handled through the Union Station yards. The coal traffic from this line and that from the main line and Chartiers Branch of the Pan Handle (which was much greater than the former) went largely through this yard to the Mahoning and Shenango valleys and to Lake Erie ports just as it does now.

The first step taken was to divert the general through business between the East and the West. The West Penn was then extended to Bolivar, so that the northwest traffic would go by the Kiskiminitas and Allegheny valleys, and a connection from the main line at Brinton or Port Perry across the river to the Monongahela Division, so that traffic for the southwest would pass down the Monongahela valley to the Pan Handle Division. For a long time thereafter the coal traffic particularly referred to continued as before, but during the latter '80s the Ohio Connecting bridge was built, and the Sheridan yards greatly increased, and by passing through these yards and then by the aforesaid bridge, and with the relief already afforded by the Port Perry bridge, practically all coal and coke traffic through the Union Station yards ceased. But after a few years, the handling of the Monongahela Division traffic through the Sheridan yards, and the dragging of the Pan

Handle tonnage up the grade out of Carnegie and through Sheridan was causing so much congestion between the Monongahela bridge and Carnegie on the main line of the Pan Handle that relief was afforded by constructing two additional tracks from the Monongahela Division direct to the Ohio Connecting bridge, connecting up the main line of the Pan Handle with the Pittsburgh, Chartiers & Youghiogheny Railway (a connection with the Chartiers Division with the latter having existed for many years previous), and constructing the Scully yards, and a cut-off from there to the aforesaid bridge.

With all of the above connections being made, there still was the problem of relieving the Twenty-sixth Street and Union Station yards of the Allegheny Valley Division traffic, destined for points on the main line west of Bolivar, the Monongahela and Pan Handle divisions. This relief was finally given by the building of the Brilliant cut-off, which at the time was extended to the north side of the Allegheny River in order that the traffic originating there would have a more direct connection to the south than by the Ohio Connecting bridge.

What has actually happened with all these changes is that the Pennsylvania System has established a small belt line, all parts of which lie within five miles of the Allegheny County court-house, except the Port Perry connection, which is within 15 miles, supplemented by the West Penn Division connecting the northwest system at Allegheny with the main line at Bolivar, but all of whose through traffic must pass within a mile of the court-house.

The Baltimore & Ohio Railroad formerly extended eastward and southward only. It could reach points to the north, with business originating upon its lines only through connections with other systems. One of our earliest recollections was a narrow-gage railroad from Allegheny to Butler and for points in Lawrence County. It was known at one time by the name of the Pittsburgh, New Castle & Lake Erie. We should judge that it and its immediate successors experienced more ups and downs (principally downs) than any railroad line built in this district. It was rechristened the Pittsburgh & Western Railroad, extended to New Castle, and made standard gage. The Baltimore & Ohio became interested in this line, and the Pittsburgh Junction Rail-

road was built by way of Laughlin Station and Thirty-third Street to connect it with the Baltimore & Ohio. About the same time, and probably with a full understanding between the interested parties, a new organization, known as the Pittsburgh, Cleveland & Toledo, built from New Castle Junction on the Pittsburgh & Western to a connection with the northwest lines of the Baltimore & Ohio at a point now known as Willard. Existing lines running to Cleveland and Painesville, Ohio, were taken over. All these lines were welded together under the Baltimore & Ohio Railroad, as a result of which there has been added to the traffic of the Pittsburgh district much through business.

The Pittsburgh & Lake Erie Railroad, a part of the New York Central System, is so situated, and its through business aside from coal and coke is so small, that it does not impose itself seriously upon these lines, the local tonnage of which compares favorably in amount with any railroad line in the country.

Coming again to the question of whether the local railroads have reached their limit in capacity for handling traffic, we would say that we have some circumstantial evidence on that point. It is pretty generally known that the Pennsylvania System officials have been considering plans for increasing the capacity of the track system in this locality and that much investigation has been made upon the ground looking to the building of detour lines that will by-pass through business entirely outside the industrial and populous district. During the World War, greater attention had to be given this district than any other interior district—first, on account of the important part that the products of this community played in the conduct of the war; and, second, on account of the congestion that hampered our railroads during that period because the capacity of our transportation system had been fully in use during the normal times preceding the war. Two years ago the War Department, acting under a general thought of the officers of that department that our transportation systems should be amended and extended so that they would be able to meet future emergencies resulting from war activities, asked for a special report on local conditions. We are assuming the privilege of quoting from a letter written by an official of a local railroad in

reply to a letter addressed to him by the War Department:

> "It is evident that aside from any relief which may be essential as a war measure, the day is not far distant when the Pennsylvania Railroad, the Baltimore & Ohio and other carriers, operating through the Pittsburgh district, must find some means of diverting, through some direct and unobstructed route, the heavy traffic which has been and is now overburdening their present facilities. This is a matter of common knowledge among railroad officials."

We are therefore encouraged to feel that we are justified in bringing before you our own general plan for meeting the future problems of our railroads. We will consider the problem with respect to freight traffic alone, as the passenger, mail and express traffic thrives best where the most congestion exists, and therefore the present method of handling these forms of traffic must continue. And we will confine ourselves to the methods of relief for the Pennsylvania System, as any plan that will fully solve the needs of that system can subsequently be adjusted to aid other systems, as any new lines that may be necessary will intersect the busy lines of the other companies.

The Pittsburgh district with respect to railroad matters is understood to be all that territory lying within a circle of 40 miles radius, having its center at the Allegheny County court-house.

This district is said to be the greatest traffic-producing area in America. Available statistics covering the past seven years would indicate that the value of its annual production is about $2,000,000,000. The fundamental reason why industrial operations are carried on upon such a large scale is the enormous deposits of bituminous coal within and in general to the south of the district. This abundant fuel, besides furnishing the power for local manufacturing purposes and light and heat, is carried in the form of coal and coke to the east, north and northwest in such quantities that at times our railroads must favor this traffic by placing embargoes upon other commodities in transportation.

It is estimated that in the year 1920, 20 per cent. of all the bituminous coal of the United States was mined in and about this district, in amount about 100,000,000 tons. Probably one-fourth of this, or 25,000,000 tons, was moved by water, leaving 75,000,000 tons to be moved by rail to local plants and distant points. As this coal moves from its hiding place it meets immense tonnages of raw materials upon which refining operations are necessary through

the application of heat, and which in the matter of weight are undoubtedly more than twice as great as the fuel necessary to reduce them to a finished state. Such finished materials, of course greatly reduced in weight from their raw state, must again be transported to market, north, south, east, and west.

Pittsburgh is the gateway for long-distance traffic passing between the East and the West and from coast to coast. While such tonnage as may originate within the district furnishes business for the railroads without encouraging the development instinct of the transportation companies (that is, the traffic forces itself upon them), through traffic must be sought out, encouraged when found, and provided with good and efficient service in order that it may be maintained. Our local railroad officials have so well understood the problems involved in securing and handling through business that an annual tonnage of probably 40,000,000 tons is handled through Pittsburgh. Here then we have two general classes of traffic, each of immense proportions, which up to this time have been handled upon the same main tracks within this busy district.

While Western Pennsylvania is peculiarly blessed with natural resources, which in turn have brought into existence a most wonderful network of railroads, its topography presents most serious problems in railroad construction and unusual difficulties in operation. The ridges that separate its watercourses, both large and small, are generally about four hundred feet above the level of the main streams. The valleys are comparatively narrow, flanked by hillsides with steep slopes and following tortuous alignments. The locating engineer when he can confine his work to the valleys will generally meet only with simple problems, but woe betide him if he has to take to the hills.

The water falling upon the district drains finally to the Ohio River, of which the three main tributaries are the Allegheny, Monongahela, and Beaver Rivers. The Ohio flows in a northerly direction from its source, but at the mouth of the Beaver it swings to the left and finally flows directly south. One following the stream will find himself, after traveling 90 miles, at an air-line distance of 45 miles from his starting point. By the longer route a water grade may be found. It requires maximum grades of

nearly one per cent. for a practical railroad location by the shorter route. These facts fairly illustrate the difficulties that must be met if the main river valleys cannot be followed in planning additional facilities.

Secondary to the main tributaries to the Ohio, and which are again tributaries to them, are the Youghiogheny and Kiskiminitas Rivers, and Loyalhanna and Connoquenessing Creeks. Within this district there are various other smaller streams that lend themselves to grades of 0.5 of one per cent., or less, through a part of their course, such as Raccoon Creek, Chartiers Creek, Peters Creek, Ten-Mile Creek, Redstone Creek, Big Sewickley Creek, Turtle Creek, Bull Creek, Breakneck Creek, Brush Creek, and several others. The five most important streams—the Ohio, Allegheny, Monongahela, Youghiogheny, and Beaver Rivers—have at least one railroad on each of their banks throughout the district, and in the case of some of these streams there are two railroads on one side for a part of the distance. The widths of the valleys vary from an average of a half mile on the Ohio to less than a quarter of a mile on the smaller streams. For 40 miles from Pittsburgh along these rivers are the principal industrial plants of the region. All the level land except what is used for residence purposes is so well taken up that there is comparatively little room left for the expansion of manufacturing. The now existing plants and the railroads that serve them, where they exist together, occupy all the space between the watercourses and the hillsides, and the operations of both are much congested, making railroad service difficult in the extreme.

Besides those railroad lines that follow the watercourse grades of the main streams, there are others that occupy the valleys of the smaller streams, and as they adopt as direct courses as possible they pass from one main valley or plateau to another. Such lines must be satisfied with grades of 0.4 of one per cent., or more, unless the locating engineer has his nerve with him and keeps his line in close communion with the hilltops and spans the main valleys with structures of fully one hundred feet in height.

The river valleys that would offer lower grades for railroad lines can accommodate no more lines. And such lines as are now in operation there should be relieved of as much traffic of a

through nature as possible, so that the local traffic can be better handled; or, in other words, the through traffic should be bypassed around the densely populated communities that lie in the valleys of the Allegheny, Monongahela and Ohio Rivers lying within this district, and measures should be taken so that the greater tonnage could be moved over the existing and proposed tracks in such manner as will be necessary to perform the quickest possible service.

The through traffic by way of the Pittsburgh gateway moves from west to east and vice versa, and by far the greatest part of it moves by the Pennsylvania Lines. In addition to that, there is the large coal and coke traffic originating to the south and southeast of Pittsburgh, that is now carried through the congested railroad tracks of the district to points beyond. This moves principally northward to the Mahoning and Shenango valleys and to Lake Erie ports, while a considerable amount of the coke manufactured in the district and to the southeast moves to the northwest and a lesser amount to the west.

While the Pennsylvania System enjoys the greatest share of general traffic, the coal and coke traffic is more evenly divided among the three great systems of railroads in the district.

Coming from the east the main line of the Pennsylvania Railroad finally emerges from the Allegheny Mountains at or near Blairsville, and for some miles has been following the Conemaugh or Kiskiminitas River. Therefore we need go no further east than the Laurel Ridge Mountains to seek a point of divergence for detour lines. At Pittsburgh the freight from the east separates, the greater part of it going to the northwest system, and therefore we should first consider a line from the vicinity of Blairsville that would by the most practical route, economy of construction and future operation both considered, strike the northwest lines west of the Pittsburgh district.

By an examination of maps outlining the geography and topography of the district, we see that we should get directly from the Allegheny River valley to the Beaver River valley if we can. As the Kiskiminitas River valley is the easiest route as far as the Allegheny River, and the Pennsylvania already has a double-track line in that valley, we naturally follow that line until it reaches

the Allegheny; and when we reach the latter, we search for the least number of ridges, and at the same time the lowest points in the summit ridges that may be in our way. In reviewing the general direction of the streams entering the Allegheny from the west and their relations with streams of like character emptying into the Beaver, we find for our purpose watersheds with headwaters so situated that the crossing of but one summit is necessary. We may go up Buffalo Creek and then on to Thorn Creek, and thence down the Connoquenessing; or we may go up Bull Creek, passing into Glade Run and then to the Connoquenessing. The first route is the shortest to the Beaver River by about five miles, but the elevation of the grade line of the latter at the summit would be about one hundred feet lower than that of the former. Furthermore, the procurement of a given rate of grade would be much cheaper in point of cost by the longer line. We determine therefore that our route should follow Bull Run and Glade Run.

As we approach the Beaver River by way of the Connoquenessing, we determine that we should reach Homewood Junction on the west side of the Beaver. At this point the line to Chicago leaves the Beaver and turns due west, while the line to the Mahoning and Shenango valleys and Lake Erie ports continues up the valley. To connect our proposed line with the present lines at or near this junction, we must cross the Beaver at an elevation of about 200 feet above the stream. A spur of great height lies in the path of a direct line from the plateau of the Connoquenessing valley to the point of the crossing. A tunnel of about one mile in length will be necessary.

This line, if built, should be double tracked. It would connect the double track of the Conemaugh Division with the double track of the Northwest Division. Over it could be passed all the through freight that now goes by way of Pittsburgh and the Conway yards. A ruling grade of 0.7 of one per cent. compensated on each approach to the summit can be secured within a reasonable cost. This grade can be reduced to 0.5 at a greater cost, which increased cost, however, might not be justified.

This new line is 43 miles in length. Used for through business, it replaces a line of 61.5 miles long. It is at a disadvantage as against the longer line with respect to grades; but this difference

is not as serious as it looks, considering the grades of adjoining sections of main track, both east and west of it, and which, with it, form a continuous line.

The planning and constructing of such a line as proposed does not rest wholly upon the points which we have developed. It must be considered from the standpoint of the character of the power that should be used upon it; whether fuel and water stations are to be provided for it; and whether, in the rearrangement of the traffic that will pass over it, new terminal points must be created. We have not undertaken to develop such matters, as they would require a study of data which we do not have at hand.

We have heretofore called attention to the large bituminous coal area to the south of Pittsburgh, and have given it credit for making this district the greatest traffic-producing area in America. There are two seams of coal in this vicinity recognized as of sufficient thickness to be worth mining under present economic conditions. The upper is the Pittsburgh vein, and the lower is the Upper Freeport vein. The Pittsburgh vein runs out near the top of the hills on a line generally east and west and through the city of Pittsburgh. Its greatest dip is to the southwest. For many years it has been mined at its crop by means of drift mines along the Monongahela River and southwestwardly in the valleys of the smaller streams to the point where it finally disappears from view. So large have been the operations along the outcrop that relatively there is not much of this coal that can be mined on the drift, and so shaft mines to the south of the main crop lines must be used, and have been used, in further development of this coal. The mining operations are moving slowly southward and away from the main lines of the railroads that at present haul the coal to market, and either these lines that now feed into the main lines will have to be materially lengthened, or a new set of main lines will have to be built, so that underground haulage will be held within reasonable limits. The coal, in finding its way beyond the local market, has had to pass through the Pittsburgh district from the south, or at least pass over portions of the main lines that have reached, or shortly will reach, their capacity for moving traffic. This traffic amounts to about 15,000,000 tons a year, and by-passing this traffic around the district will further aid in the

general plan of relief we are now considering. The course of the Monongahela River from the point where it crosses into Pennsylvania is due north. While there is an immense body of coal lying between it and the Youghiogheny River to the east, the territory to the west is an important area of coal extensions into West Virginia, and it will be within this area that the great developments of the future, so far as the Pittsburgh district is concerned, will occur.

To have this coal move to the north, and avoid Pittsburgh, it should naturally pass to the west. For some years the upper Monongahela valley will continue to be the main outlet. It would therefore seem that the coal not intended for local consumption should move from the mines within the Monongahela valley far enough northward to secure the greatest amount of coal traffic, and yet not so far as to impose upon the congested manufacturing districts. It would appear that Mingo Creek, which discharges just below Monongahela City from the west, is the first branch stream that lies in the general direction that should be followed, and we select it as a part of the new route.

Investigating the country to the north of Mingo Creek, we find Raccoon Creek lying in a very advantageous position for continuing our line northward. It is a stream of easy grades, and discharges into the Ohio at a sufficient distance below Pittsburgh to miss local traffic. A Mingo-Raccoon line encounters one serious disadvantage, and that is that the two main branches of Chartiers Creek must be crossed in passing from the former to the latter stream. However, when we reach the Ohio River we are in a position to connect up with all the lines of the Pennsylvania, New York Central, and Baltimore & Ohio Systems leading to the west and to the north; and, incidentally, we have intersected the Southwest System at Burgettstown and the Chartiers Division near Canonsburg, and the Pittsburgh & West Virginia Railway near Hickory.

We believe that with a north detour provided, and a line tapping the coal fields to the south that would by-pass to the west a large percentage of the through coal and coke traffic out of the main river valleys, a considerable period of time will elapse before the detouring of the through business between the eastern lines and those leading to the southwest need be considered. When the

necessity for such a diversion does arise, it will undoubtedly be found that the line proposed in this paper for tapping the Pittsburgh coal area could be made the major part of such a south detour.

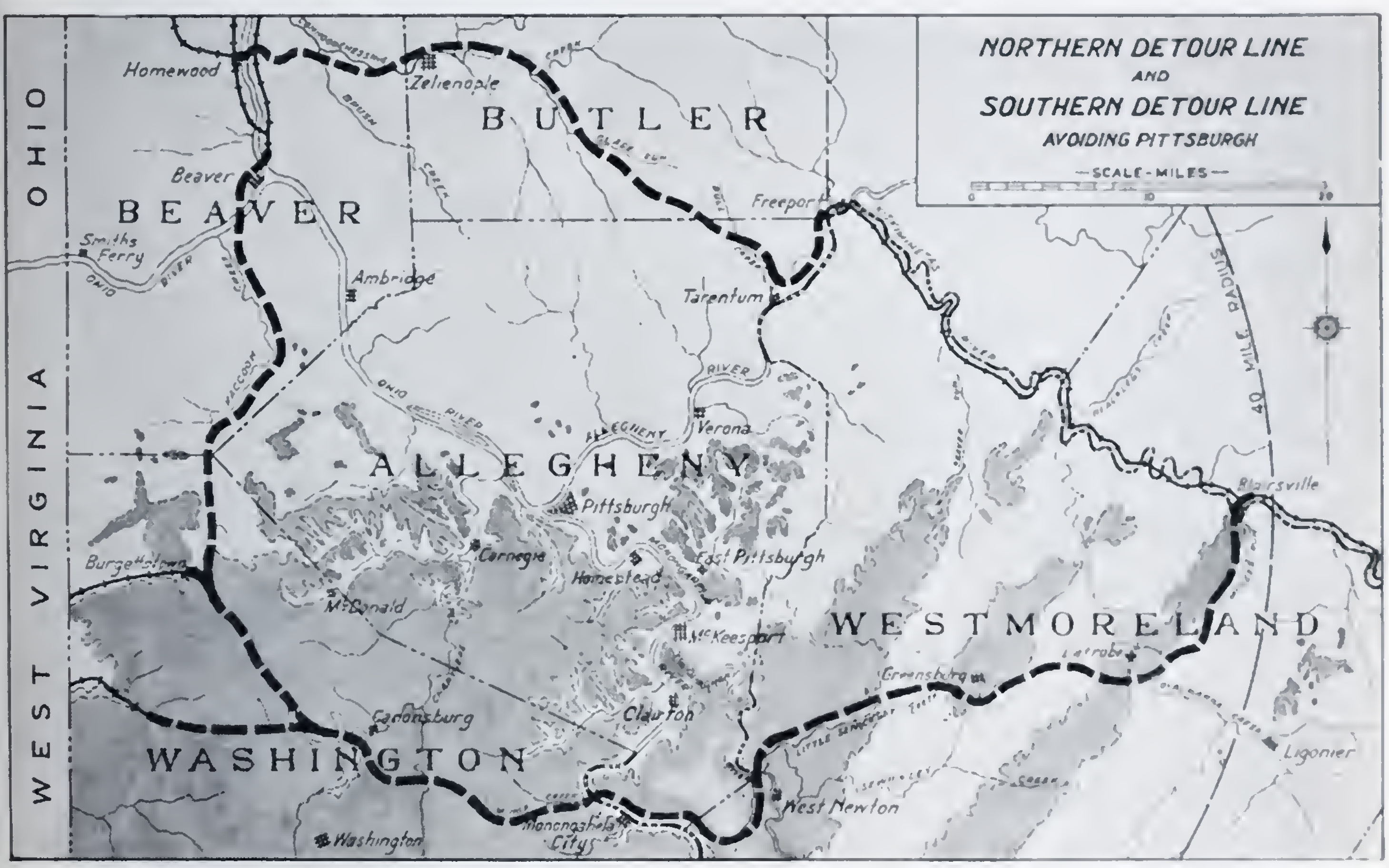

Fig. 1. Coal Fields and Proposed Detour Lines.

The map shown in Fig. 1 indicates the location of the coal fields and the routes proposed for the detour lines.

The maximum inherent capacity of a railroad can be attained, in the present state of the art, only by electrification. The proof of this statement can be given in few words:

1. The electric locomotive has practically unlimited capacity. The multiple-unit system of control permits one man to control simultaneously any number of electric locomotives that are coupled together. This system, together with the fact that the entire power station is back of the locomotive, entirely eliminates the question of power as a limitation of traffic; the lengths and weights and speeds of trains need be limited only by strength of draw-bars and considerations of safety.

2. The lengths of divisions will bear no relation to the present engine divisions under steam operation. They will be fixed solely

by traffic considerations, since the electric locomotive can stay on the road several days at a time. The usual mileage between inspections is 3000 to 4000, so that a locomotive could easily make the round trip between New York and Chicago in one run. One of the Chicago, Milwaukee & St. Paul locomotives made a continuous mileage of 766 in 24 hours, while another made over 12,000 miles in one month of 30 days on a schedule that did not permit more than one run of 440 miles in a day.

3. The electric locomotive does not have to stop for fuel and water.

4. The ruling grade on an electrified line may be much greater than on a steam railway because of the greater power and the fact that the maximum draw-bar pull is exerted with at least 33 1/3 per cent. adhesion, while the corresponding maximum of the steam is at 22 to 25 per cent. The length of line may therefore be shortened and its cost of construction reduced.

5. Tunnels may be used to a much greater extent, since with the electric locomotive they form no obstacle whatever. The Simplon tunnel under the mountains between Switzerland and Italy is 13 miles long and is operated electrically. A tunnel under the English Channel would be just as easy to operate with electric locomotives as so much distance in the open air. Tunnels frequently form the neck of a bottle on a railway because of the limited number of trains that can pass through in a day.

6. The capacity of terminals is enormously increased by electrification. Tracks may be on two or three levels, and may be entirely under cover of station, office buildings, post-office, hotels, warehouses, etc. Multiple-unit service greatly increases the number of trains that can be handled.

Fortunately all of the above statements have been proved in actual service, and are being proved every day: On the Norfolk & Western, where two electric locomotives take a 3250-ton train up a two per cent. grade at 14 miles an hour, where formerly three of the largest Mallet steam locomotives with the same train could make only seven miles an hour; on the Chicago, Milwaukee & St. Paul, where electric locomotives now cover the entire electrified zone of 440 miles in one run, crossing three mountain ranges en route without assistance of a helper; in the tunnel on the

Grand Trunk at Port Huron; in the Hoosac tunnel of the Boston & Maine at North Adams; in the Loetschburg, the Simplon and the St. Gothard in Switzerland, and many others; in the great terminals of the New York Central and of the Pennsylvania Railroad in New York, the Broad Street terminal of the Pennsylvania Railroad in Philadelphia, and in the great classification yards of the New Haven, where the electric switchers stay out a month at a time.

Having shown the necessity of electrification to secure maximum capacity, a few words as to its other advantages may be permitted. One of these, which has been thoroughly demonstrated on the Norfolk & Western Railway and the Chicago, Milwaukee & St. Paul Railway, is regenerative braking—a system whereby the motors on the locomotives are used as generators on down grades and utilize the power ordinarily lost in brakes to generate electricity, which is returned to the line, where it may be used by the nearest train taking power. On the Norfolk & Western the speed is held on down grade at a constant speed about five per cent. above the speed ascending the grade, on account of the motors being of the induction type. On the Milwaukee the speed is variable at the will of the operator over a wide range, and the motors in this case are of the series direct-current type. It is a truly wonderful system, which one can scarcely appreciate without riding a locomotive down the heavy grades on one of these railroads. The steady holding power of the locomotive gives one a sense of security that can never be felt when the train is held by the alternate application and release of air-brakes, and the consequent alternate acceleration and retardation of the train. With this system, the well-known difficulties due to worn brake shoes, overheated tires and defective brake rigging are eliminated, as the air-brake system is used only in emergencies.

While the greater safety in descending grades is worth all it costs, the power regenerated by the locomotive will, in some cases, be quite a considerable item. In any case, it helps to reduce the average power consumption as compared with what would be required for level track.

Other great advantages of the electric over the steam locomotive lie in the low cost of maintenance and the greater mileage of

train crews, which are a corollary of the long continuous mileage. With the higher wheeling speeds and longer runs the efficiency of the train crews will be greatly increased.

For these reasons, we recommend that the railways of the entire Pittsburgh district be electrified—not all at once or immediately, but in the near future, because it will eventually be necessary for the growth of the city.

It is well known that the Pennsylvania Railroad has for a long time had under consideration the electrification of the Altoona-Johnstown grades, and it is well known that some years ago they built for this service a gigantic electric locomotive, called the FF-1. It has six pairs of drivers, each carrying 70,000 pounds, and two pony axles, each carrying about 50,000 pounds, so that the total weight is approximately 520,000 pounds. The locomotive has a normal speed of 20.5 miles an hour and a continuous tractive effort of about 73,000 pounds, giving a continuous rating of 4000 horse-power. The one-hour rating is 4800 horse-power. With an adhesion of 33 1/3 per cent. the locomotive will develop a tractive effort of 140,000 pounds at any speed up to 20 miles an hour.

This locomotive is of the so-called split-phase type, with induction motors like the Norfolk & Western locomotives mentioned. Its single operating speed of 20.5 miles per hour is especially suited for pusher service on the east slope. A lower speed of 10 miles an hour is also provided for yard movement. This locomotive is now in service as a pusher between Philadelphia and Paoli on the main line of the Pennsylvania Railroad.

The Pennsylvania Railroad is now building another locomotive with series motors giving variable speed characteristics. It is known as the L-5. This locomotive is of the 2-8-2 type, four pairs of drivers each carrying 75,000 pounds. This engine has a speed range up to 35 miles an hour, and a normal speed at continuous rating of 23 miles an hour. The continuous rating is 3000 horse-power, and 50,000 pounds tractive effort. The maximum tractive effort is 100,000 pounds.

In considering the electrification of the north detour we have assumed that the Altoona grade would be electrified before the detour is built, so that the electrification of the latter would be simply an extension of the hill electrification. To secure the great-

est economy in operation it would seem that the trains should be made up at Altoona and run straight through to Homewood Junction, or to Canton, Ohio, if preferred. The distance of 145 miles from Altoona to Homewood Junction could easily be covered in six hours, even allowing for some delays. The average wheeling speed over the north detour would be about 28 miles an hour east bound and 29 miles west bound, so that the 82.5 miles of the detour could easily be covered in three hours either way. The west-bound train would make an average wheeling speed from Altoona to Blairsville of at least 25 miles an hour and take a total time of 2.5 hours, making 5.5 hours wheeling time between Altoona and Homewood Junction. The east-bound trains would require 30 minutes longer on account of the lower speed both up the west slope and down the east slope.

We have assumed a regular spacing of trains of one an hour each way. The L-5 will, with the help of a pusher on the east slope, haul a west-bound train of 3300 tons clear to Homewood Junction. East-bound trains of 3500 tons can be handled all the way with the help of a pusher on the heavier grade on the west slope. With 24 of these trains a day each way, an annual tonnage of 50,000,000 can be handled over the north detour. This is 25 per cent. more than now passes through Pittsburgh. It will be easy to haul four times as much by doubling the size of trains and spacing them half an hour apart. As to what the maximum traffic could be, we would not even hazard a guess, as it would depend entirely on the freedom from interruptions on the road.

In any case, however, we want to make a plea for scheduling of freight trains just the same as passenger and mail trains. Regularity of operation certainly conduces to efficiency of operation and to securing the maximum capacity out of the track. We know there are objections to scheduling freight trains officially. If the objections are sufficiently strong to prevent it, then have an unofficial schedule that will at least give a uniform spacing of trains. This will not only give a better load factor on the power-station, but will decrease the number of locomotives necessary for a given service.

For instance, with one train an hour each way, the north detour could easily be handled by eight locomotives, allowing a

good lay-over at each end. We have assumed that four more locomotives would give ample allowance for spares and stopping, making a total of 12 locomotives for the north detour. With regular spacing of trains there would be a fine load factor, since the average load at the power-station for this detour would be approximately 14,500 kilowatts and the peak-load only 22,000 kilowatts. The energy required per ton mile of trailing load is less than the ordinary 25-watt lamp uses in one hour.

Assuming that the Pennsylvania Railroad will purchase power if a supply is available, we have not considered a power-house for this line. We have estimated on a two-circuit transmission line on a single line of steel towers, outdoor type; and eight substations, five of 4000 kilovolt amperes and three of 6000 kilovolt amperes. We have assumed that the trolley construction and bonding would be similar to that on the main line at Paoli, and that 12 L-5 or similar locomotives would be required. On these bases, the total cost of electrification of the north detour would not exceed $5,600,000. The benefit to the railroad and the city from such a line would be incalculable.

In concluding, we desire to acknowledge the great assistance of Mr. T. C. Wurts in making estimates of power, costs of construction, etc., that are given above.

DISCUSSION

MR. HARRY J. LEWIS:* One of the live questions in the expansion of railroad facilities is the point of contact between the driving-wheel of the motive-power department and the rail-head of the maintenance of way department. In shoving up the driver loads we long ago passed the elastic limit in this contact and have been cold rolling the rail-head away to the sides. The tractive effect of the driver tends to increase this flow of the metal. The proposed load of 75,000 pounds on an axle puts the wheel load of 37,500 pounds on an area of contact which probably does not exceed 1.25 square inches, if the Purdue static tests are reliable. When the impact and tractive forces are added to this, it is not hard to see how the cold rolling is effected. The load is carried by a mutual deformation of metal in wheel and rail, and the depression varies directly with the load.

The Mallet type of engine is an attempt to spread the tractive force over more drivers than can be coupled into a single rigid frame and thus afford a chance to reduce the wheel loads.

The load of an axle cannot be distributed over much more than four lineal feet of track in the contact between rock ballast and the supporting soil, or 42.5 square feet. An axle load of 75,000 pounds means about 1770 pounds per square foot on the soil under the ballast. It is not hard to see why the track goes down under heavy traffic in wet or thawing weather.

If electric traction will secure 33 1/3 per cent. adhesion, as against the 20 to 25 per cent. of the steam-engine, it would seem that this advantage should be used to reduce the axle loads rather than to prolong the present abuse of rails and tires.

MR. S. A. TAYLOR:† One thing I noticed in the statistics of some years ago—especially the last three decades of the last century—was that practically half of the coal produced in the world was produced in the United States, and practically one-half the coal produced in the United States was produced in Pennsylvania, and practically one-half the coal produced in Pennsylvania

*Consulting Engineer, Pittsburgh.
†Consulting Engineer, Pittsburgh.

was produced within a radius of 40 miles from Pittsburgh. That is not exactly the situation now. The figures given by Mr. Davison were very close to that ratio, and they will never again reach the high percentage of the output of coal either in the United States or in this district. The reason is very obvious. A great many of the states he mentioned had not yet developed their coal lands. Since then some of them have developed very rapidly.

Again, in 1870 and 1875 it was stated we were going to run out of coal in 100 years. To-day we have more coal than we had then, after all this development. Now in each state we are finding new seams of coal, and the final working out of the coal is very far in the future.

Progress is being made in the use of lignites and the poorer grades of coal. The United States Bureau of Mines has just recently completed experiments on the lignites of the Dakotas, making out of these lignites a fuel almost as good as anthracite; so in the future I think you will find that a great deal less coal will go from this district, and that which does go will go largely from the southerly end of the district. Our gateway will not be so congested in the future as it has been in the past, because, as Mr. Davison pointed out, a large part of the coal that was available by drift mining is gone. As it goes farther down into Greene and Washington Counties I think there will be other cut-offs that were not shown on Mr. Davison's map, which will take a large part of that coal even farther south than indicated by Mr. Davison. A large part of it will come through another line that comes down Wheeling Creek (that will almost bisect the territory adjacent to Mr. Davison's line by Mingo Creek) and the Baltimore & Ohio Railroad from Fairmont to Wheeling, on which there will be easy grades available.

I think there will be a great deal more coal produced in this district long before the coal from these farther removed areas will begin to come into this region for fuel needs. We have below us quite an area of thick Freeport coal, which is now being mined quite extensively, and we are finding extensions of this field in small bodies. It is not regular like the Pittsburgh coal. There is one development of about 4000 acres just recently made out near McKeesport. I drilled a little farther up the river and located

about 2000 acres. We find this lying in lenses around this section, and I think we will find considerably more coal available for the future of Pittsburgh than we anticipated 15 to 20 years ago.

I do not know positively about the next vein below that, because our drillings have not been extended that far, but there is another seam below the Freeport, the lower Kittanning, which is usually very good.

There are quite a number of cut-offs that were not mentioned by Mr. Davison—one at least of which we have made actual surveys. A very great difficulty in grading a cut-off is the high narrow tract of land between the Youghiogheny and the Monongahela, about 400 feet above the river. This makes a very heavy grade. We carried one line from Greensburg down the Hempfield branch, crossing the Youghiogheny River and on down to Elizabeth, and we had a grade of about two per cent. ascending from the Youghiogheny River and a grade of a little more than that quite a distance down the Monongahela River. So, while that is a cut-off, it would not be a very good one with such heavy grades. Mr. Davison's project is a better line than the one just mentioned. There are quite a number of short cut-offs which the Pennsylvania Railroad could make to advantage—more than can be mentioned to-night—but that would not necessarily relieve the Pittsburgh district very much unless it would be that part of the coal lying on the Monongahela River could be taken east without coming down the Monongahela River to Port Perry. A short line from New Geneva up to Fairchance, and several other short lines that could be built, would help to relieve congestion in and around Pittsburgh.

MR. GEORGE S. DAVISON: Mr. Taylor talked of the cut-off by Elizabeth. I located a line there in 1882, and the same year I located a line down Cross Creek to Wheeling, so his reminiscences are interesting to me.

There is a gentleman here—a man with whom I dragged chain in the first gang where I ever dragged a chain—who is now a Chief Engineer, and who knows more than I do about this matter, and I want him to criticize the plan.

MR. ROBERT TRIMBLE:* Mr. Davison flatters me. I came to hear his paper and did not expect to make any remarks.

Had Mr. Davison consulted me about reminiscences before the meeting I might have helped him some. He omitted to mention the old Ardesco Oil Refinery at Woods Run. When I was a boy we were treated to many great spectacles of big conflagrations at that refinery. He also omitted to mention the Pork House Mill at Verner (now the Pittsburgh Forge & Iron Works), the Lewis, Oliver and Phillips Works in the Woods Run district, the old Harbaugh, Mathias & Owen Mill (also called the Superior Mill) and the La Belle Steel Works in Allegheny.

There is another matter which his remarks brought to my recollection. When I was a boy my father moved from Butler to the lower part of old Allegheny (then called Manchester) and brought me along with him. We came to Pittsburgh by the old Butler & Pittsburgh plank road, and from Sharpsburg to Allegheny the route was over old Ohio Street and alongside of the old canal. There I saw canal-boats in operation on the location where the West Penn Railroad now exists. I was not quite so fortunate as Mr. Davison in taking long journeys away from Pittsburgh when a boy. My first long journey from Pittsburgh was in 1876, when I went to Philadelphia to the Centennial Exhibition. Prior to that I had made some trips as far as Ashtabula, on Lake Erie, and before that time a number of trips down the river as far as Sewickley. I remember that it took us about a day to make the trip from Allegheny to Butler by the West Penn route after that road was opened to Butler. I also remember that on the Fort Wayne road the stops were very frequent. We took the train at Pennsylvania Avenue and made stops at Washington Avenue, Superior, Woods Run, Verner, Jacks Run and other places. The names of the stations between Pittsburgh and Sewickley then were quite different from those now known.

I was very much interested in Mr. Davison's paper, and I believe it is safe to predict that any detour line built around Pittsburgh on the north will not be many miles away from the location he suggested. It will, no doubt, differ in detail. The matter of grade to be used is important, whether the road be electrified or

*Chief Engineer, Maintenance of Way, Pennsylvania System, Pittsburgh.

steam operated. In regard to terminals, I do not think that any one that has to do with this relief line would favor any large yard between Blairsville and Homewood. It may be necessary to have some tracks where changes may be made in power in case the line from Altoona to Canton be divided into two stages. In regard to the proposition to run by electric power from Altoona to Canton, I am not able to express an opinion. Should the operation between Altoona and Canton be partly electric and partly steam, there must of necessity be a yard with a few tracks where changes in power can be made. With the grades and location proposed by Mr. Davison, we get a low elevation crossing the Beaver River. A crossing much higher in the air has been proposed.

I believe it was said that the railroad between Altoona and Blairsville would probably be electrified before this cut-off is built, and possibly that may be correct, because the matter of financing a scheme of this kind is of considerable moment. The railroads all over our country to-day need a great deal of money to provide facilities to take care of the business properly, and we are being called upon constantly for the expenditure of large sums of money that are non-producing in revenue. A short time ago I made an estimate of what the Lines West of Pittsburgh might be called upon to do in the way of abolishing grade crossings, and this estimate amounted to about $60,000,000. This expenditure would not produce any additional revenue; nevertheless, because of the conditions obtaining in populous cities, we will be obliged to spend considerable sums in the elimination of these crossings.

After all, the whole question of adequate railroad facilities is one of financing. The people must have enough confidence in the railroads to provide the money necessary to make needed improvements.

WATER DEACTIVATION

By F. N. Speller*

This paper is intended to describe briefly the development of means for control of corrosion by removal of free oxygen from water.

Any theory of the mechanism of corrosion must recognize the fact that oxygen and water are necessary for most kinds of corrosion, and that even in some dilute acid solutions the rate of corrosion is affected to a marked extent by the oxygen concentration. In most waters corrosion is proportional to the oxygen content. We must also consider the fact that differences in composition of ferrous metals have very slight influence on corrosion in water, but in some cases this is the controlling factor in atmosphere. In other words, both the character and the relative amount of corrosion are, as a rule, different in water and in atmosphere with different kinds of iron or steel.

The marked influence of scale formed on the surface of iron in atmosphere and in water, which is apparently controlled by conditions external to the metal, must be taken into account. These consist mostly of the hydroxids of iron with silica, carbonate of lime and other compounds in such form as to build up in some cases a very effective protective skin.

The electrochemical theory of corrosion is based on the fact that all metals are soluble in water to a slight extent. When the metal enters solution, hydrogen is plated out on the surface in ionic form. In the absence of free oxygen, polarization occurs and the reaction ceases. When oxygen is present, it combines with the hydrogen, forming H_2O, and thus permits more hydrogen to be formed and more metal to enter solution. The iron on entering solution forms ferrous iron and is oxidized to a combination of ferrous and ferric iron and finally to ferric hydrate, or rust. Other theories are held in Europe, such as the direct attack of oxygen on metal in solution and the action of colloids. With the exception of the phenomena of passive iron the electrochemical theory seems to explain the facts already known regarding corrosion in a manner satisfactory to the majority of those who have

*Metallurgical Engineer, National Tube Co., Pittsburgh.

studied this subject; and, until much more research work has been completed and the results found to be inconsistent with this theory, our faith in the electro-chemical theory of corrosion should stand.

About seventeen years ago it was shown experimentally by Dr. W. H. Walker and the writer through independent and different methods that corrosion in water, within certain limits, is approximately proportional to the free oxygen content—temperature, time, velocity, and other factors being constant (Fig. 1)

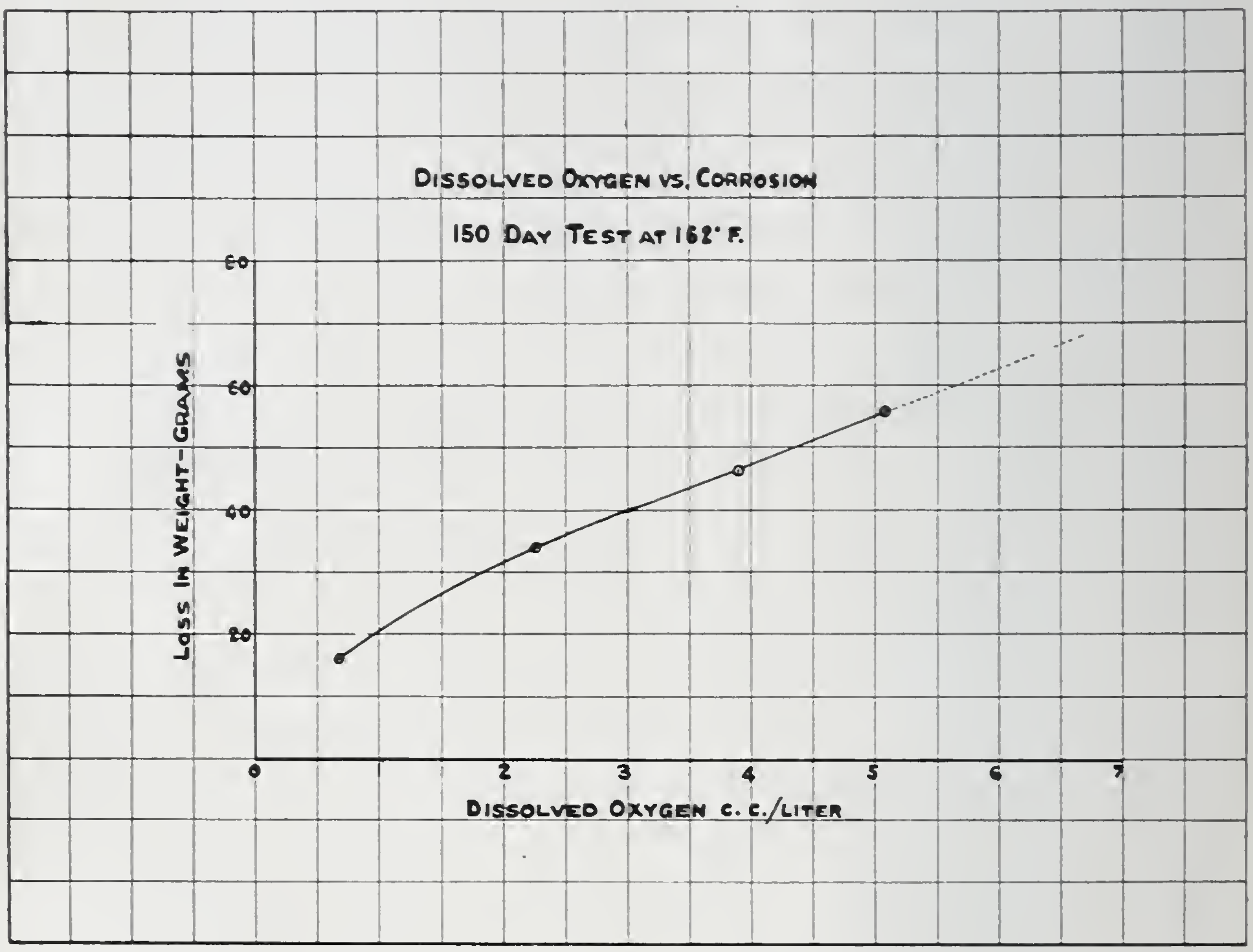

Fig. 1. Relation Between Corrosion and Dissolved Oxygen.

The influence of temperature and velocity is shown in Fig. 2. The relation of the free oxygen content of water to the pressure is expressed by Henry's law, which states that the solubility of a gas at a given temperature is proportional to the partial pressure of the gas above the solution. The solubility of oxygen in salt and fresh water at atmospheric pressure varies with the temperature.

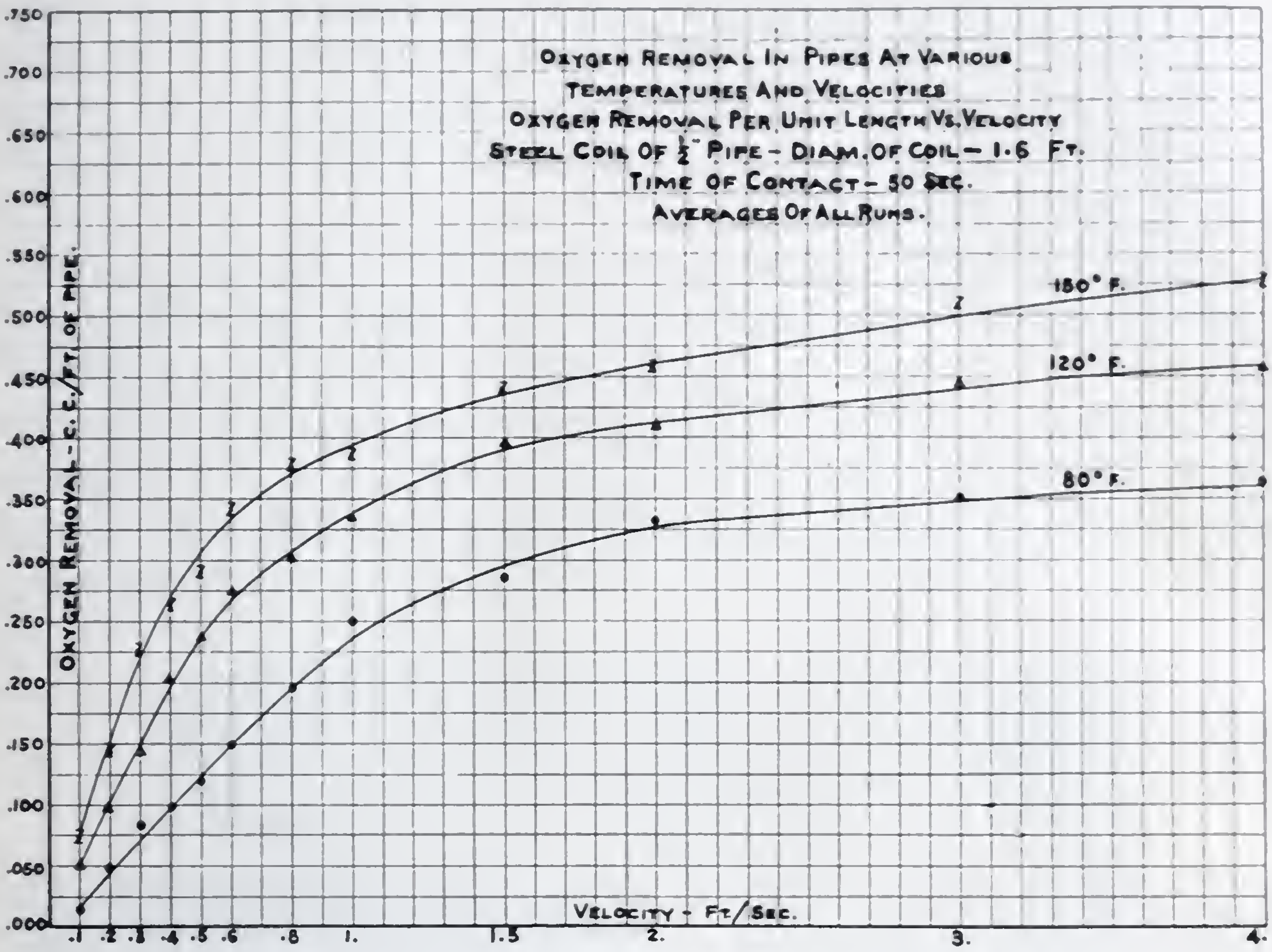

Fig. 2. Influence of Temperature and Velocity.

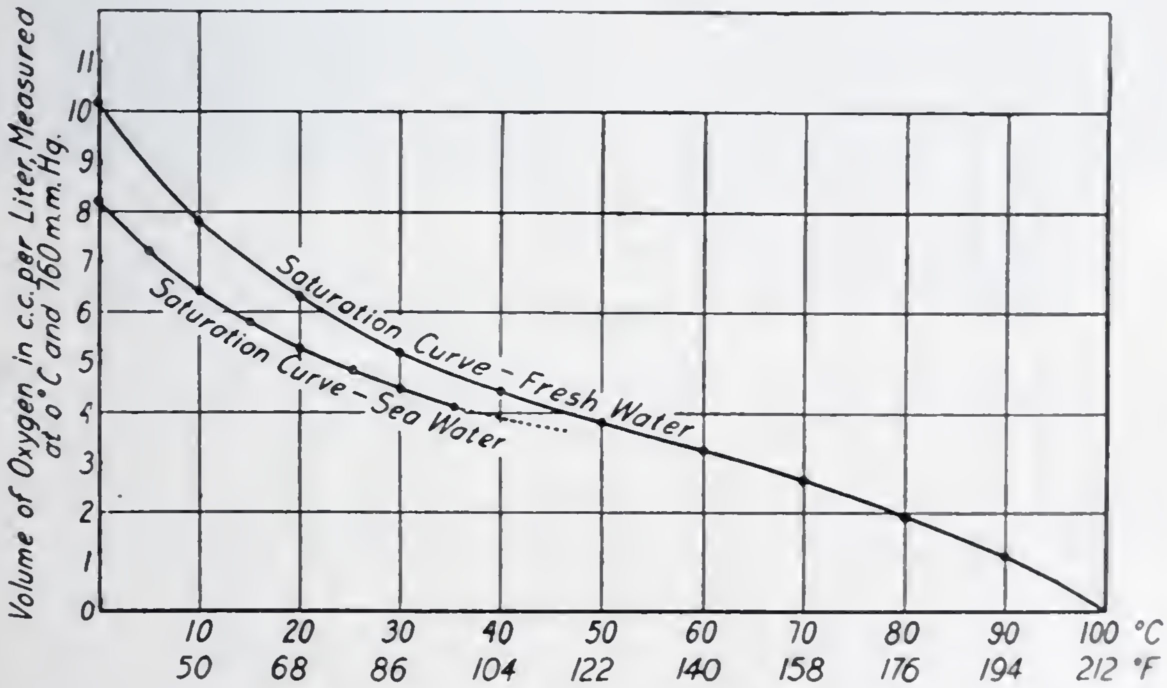

Fig. 3. Solubility of Oxygen in Water at Atmospheric Pressure (From Air Saturated with Water Vapor).

as indicated in Fig. 3. The combined influence of variations of temperature and pressure on solubility of oxygen is shown in Fig. 4.

The practical application of these principles has resulted in the development of special apparatus for the deactivation and de-aëration of water on a large scale. Most of the initial work on the design of appliances for this purpose has been carried out in the Pittsburgh district.

It may be useful to record the main steps in the development of the apparatus for removal of dissolved oxygen from water. In 1906 the use of scrap-iron was first tried by the writer to fix the free oxygen. Swarf and other forms of scrap steel were found not to be well adapted to this purpose, as the tank and contents were apt to become caked into a solid mass after some time. Iron rust occupies about ten times the volume of the metal. With this

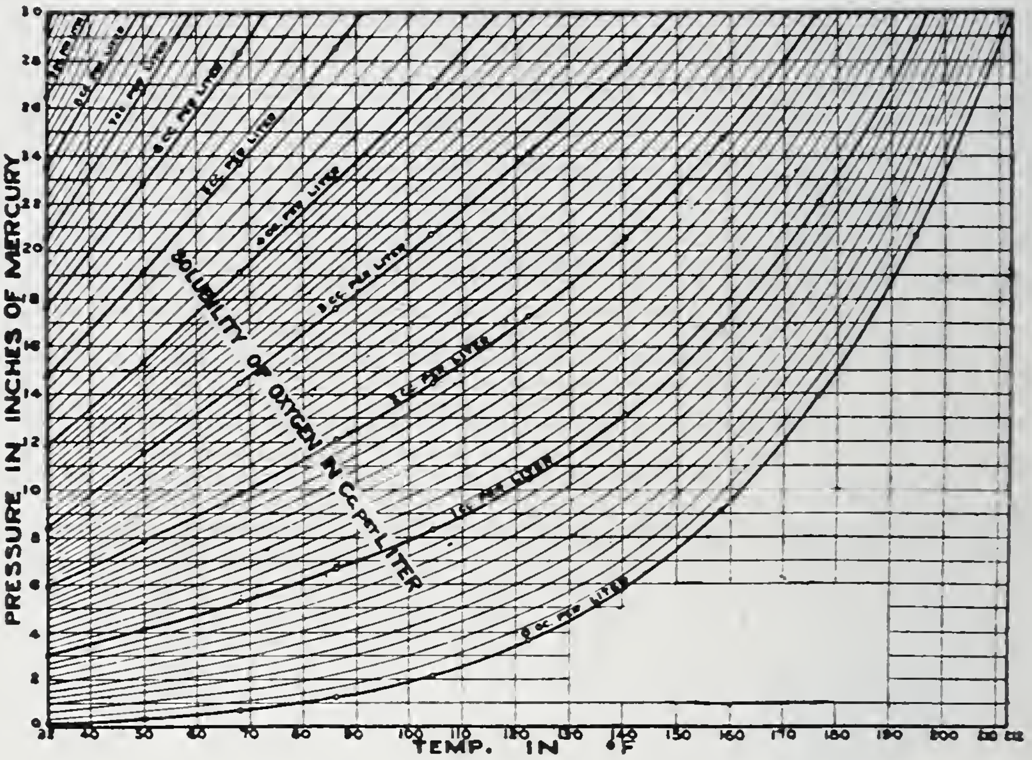

Fig. 4. Solubility of Oxygen in Water (Assuming Saturation with Water Vapor).

in mind, there was found a suitable form of steel lathing (26 Birmingham wire gage) which could be packed in a tank with a uniform density so that there would always be sufficient space for the rust without interfering with the flow of water. The rust which forms on these sheets is light and open in texture and will not pack tightly.

In 1912 the writer suggested some experiments on the removal of free oxygen by heating water under reduced pressure.

An experimental plant was put in at the building of the Mellon Institute of Industrial Research, at the University of Pittsburgh (1915-1916), but was found to be unsuitable for operation in a building of that size and was subsequently removed. However, this afforded a comparison of mechanical de-aëration with fixation of oxygen by contact with steel lathing, and showed that the latter was more simple and could be operated with less attention and cost in buildings of moderate size.

The first plant using steel lathing for this purpose was constructed in 1915 by the National Tube Company and installed to treat the hot water for the residence and laundry of the Irene Kaufmann Settlement in Pittsburgh. This plant is still in operation. Test pipe which were installed with the plant and subsequently taken out showed practically no corrosion in three years of service, whereas ordinarily serious damage was usually found in that time, as indicated in Fig. 5, showing samples from one of

Fig. 5. Pitted Sample in Service Two Years with Untreated Water; Unpitted Sample in Service over Three Years in Same Building with Deactivated Water.

these tests after three years in service. The original piping was in bad condition in 1915, but is still in use. Furthermore, it was found after a few months' operation with deactivated water that the old rust which clogged the pipes had become loosened and was gradually removed. This is probably due to the reduction and dehydration of ferric hydroxid which resulted in disintegration of the mass. Whatever is the true explanation, the result has a very important practical bearing on the problem, as the obstruction from rust often seriously decreases the flow in galvanized pipes and is often the primary cause of renewals. This has been found to occur wherever these plants have been installed to protect old piping.

There are now over one hundred plants operating on this principle. A typical view of one of the latest of these is shown in Fig. 6. Paul Kestner, in Paris, has recently introduced a modified form of deactivator, using iron scrap, but reversing the direction of flow at regular intervals for the purpose of recuperation. No records are available as to the operation or efficiency of oxygen removal in this apparatus, although we have noticed a slight improvement in deactivation when the flow of water is stopped over night.

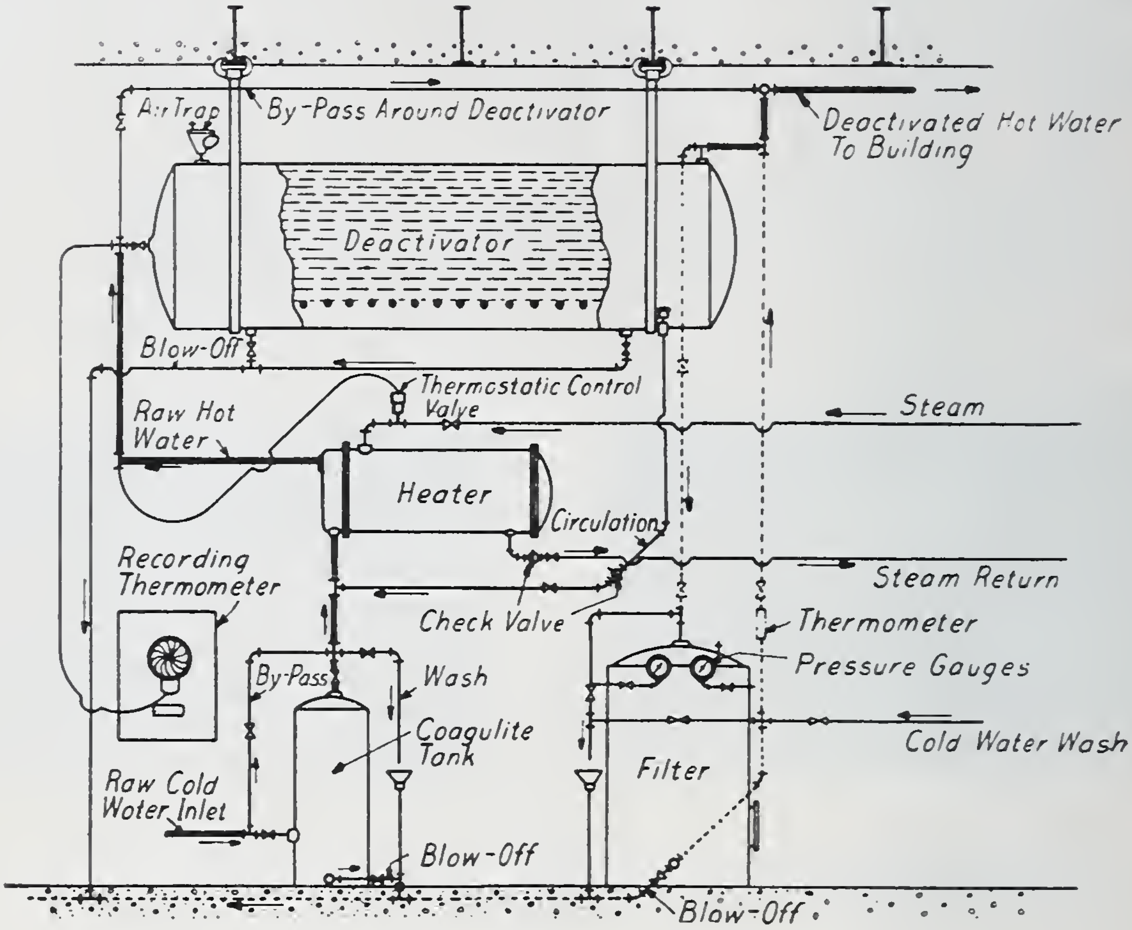

Fig. 6. Typical Installation for Water Treatment.

The use of sheet-iron was the first means to be generally used for deactivating water. Mechanical de-aëration by heating the water under reduced pressure has been used in this country and in Europe to some extent and has economic advantages where the amount of water used exceeds about 2000 gallons per hour. The well-known open feed-water heater is the simplest form of this type of de-aërator, and for many purposes is all that is needed.

W. S. Elliott, of Pittsburgh, as the result of some experiments at Mellon Institute of Industrial Research, has designed a mechanical de-aërator in which the water is superheated and

caused to flow into a low-pressure chamber. The temperature and pressure are so adjusted as to cause violent ebullition and a proportional drop in temperature of the water in passing through the de-aërating chamber. Some portion of the water is evaporated into steam in the separation process and the rest of it goes on to the service-pump line. The portion which has flashed into steam, mixed with the separated gases, is drawn into a surface condenser which is attached to the separator. The condenser is cooled by the water on its way to the heater. The steam is condensed and the condensate returned to the separator, the heat of the steam is returned to the cooling water and the non-condensable gases are

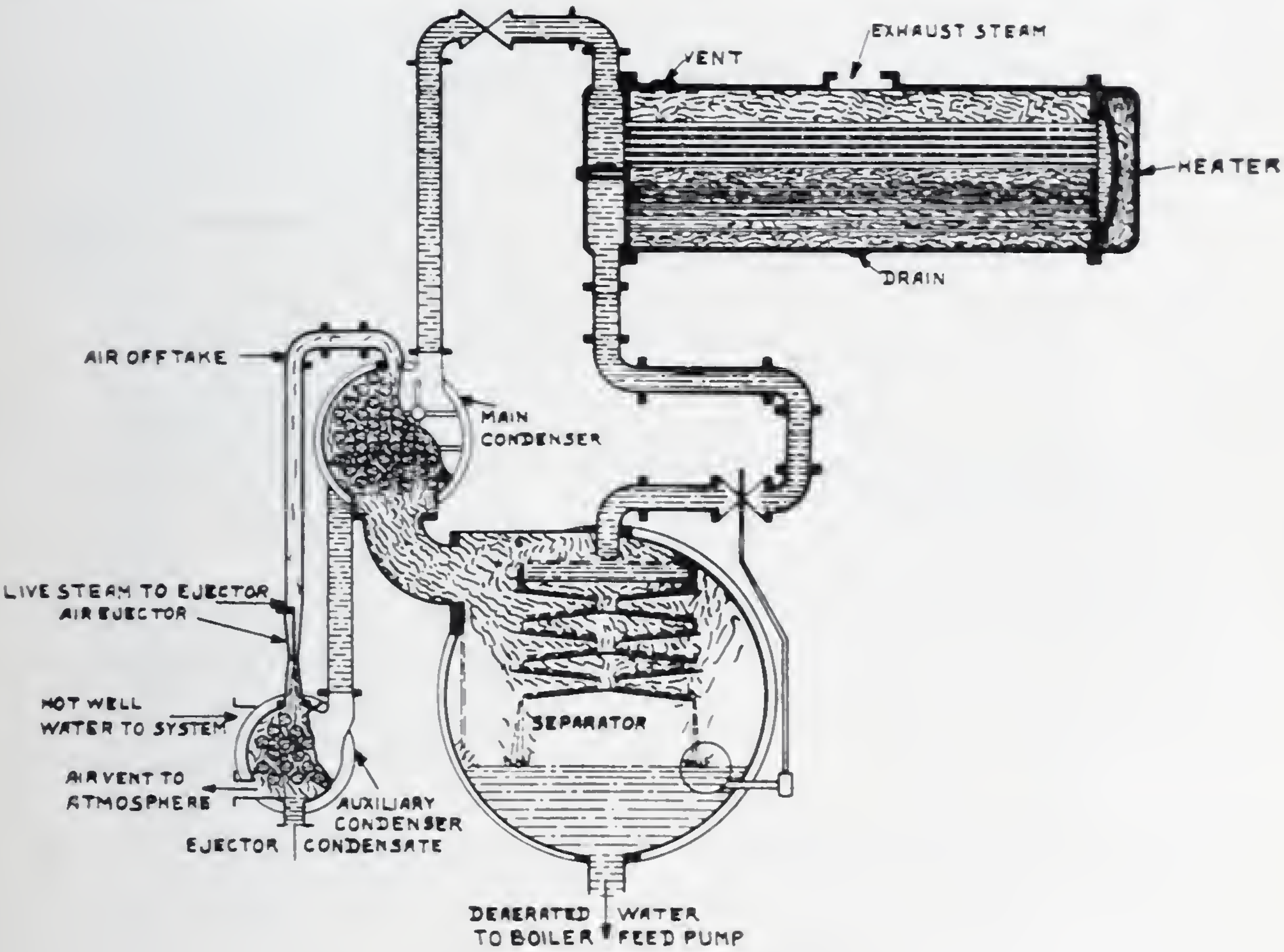

Fig. 7. Elliott Apparatus.

removed by a steam-jet air ejector. An auxiliary condenser is sometimes provided to remove the condensable gases from the exhaust of the ejector. This is indicated in Fig. 7, which shows a diagrammatic view of one form of the Elliott de-aërator. This design of apparatus seems to be well adapted to maintain the oxygen at a low point and to handle large quantities of feed-water for power-plants using steel economizers.

Another type of mechanical de-aërator (designed by the Anti-

Corrosion Engineering Company, New York), of which several are in operation in large buildings, is shown diagrammatically in Fig. 8. Here the water is heated to about 212 degrees F., with a close and simple system of temperature control, and passed over baffle trays above the water-level in a vented separator tank, at *atmospheric pressure.* Most of the gases are discharged and the temperature of the water is reduced in passing through the heat exchanger in the lower part of the separator tank, the excess heat being given up to the incoming cold water which passes through the inside of the exchanger coils. The oxygen is in this way main-

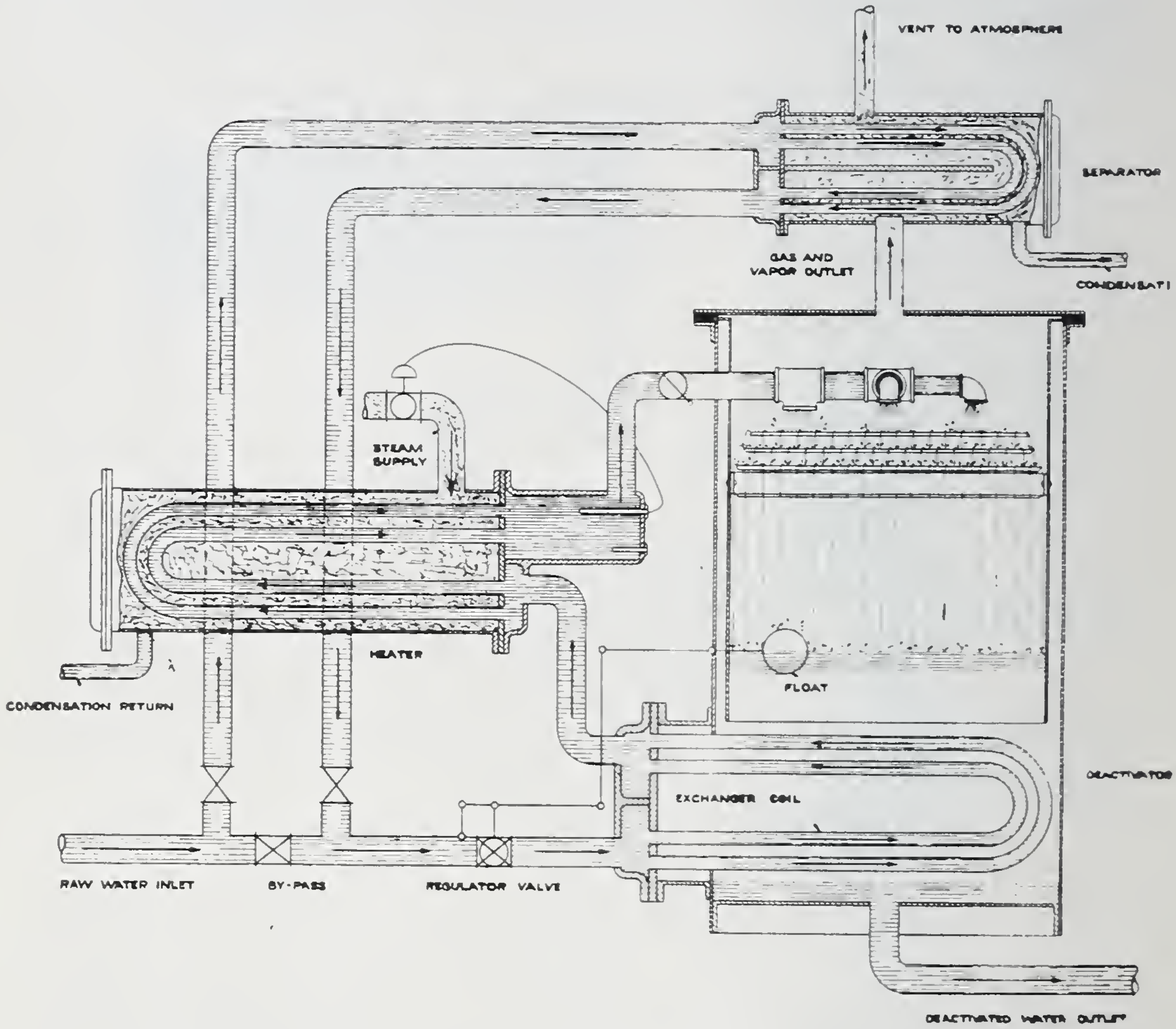

Fig. 8. Anti-Corrosion Engineering Company Apparatus.

tained below 0.30 per cent. at all times without difficulty, and by keeping the water at the boiling point the oxygen has been found to average below 0.15 cubic centimeters per liter. A small condenser may be placed on the vent to prevent the escape of vapor. This seems to embody all that is essential for de-aërating hot water for domestic use.

This or the Elliott apparatus must, of course, be placed at a high level to give gravity flow, or the water must be repumped through the building.

The H. S. B. W.-Cochrane Corporation, of Philadelphia, has developed a special type of Cochrane heater said to deliver water of low oxygen content at any temperature above 130 degrees F. This apparatus is similar in construction and principle to the standard open heater except that the steam, instead of entering above the water level, is led to a manifold at the bottom of the water-storage space, from which it rises through perforated brass laterals counter to the down-flowing water. Any non-condensable gases issuing from the top of the tray stack pass through a pre-cooler or condenser through which passes some of the cold incoming water. The apparatus may be operated under a vacuum if the de-aërated water is required to be delivered at a temperature below 212 degrees F. If a steam ejector is used, a small surface condenser is provided to take care of the exhaust from the ejector.

In some cases where very complete de-aëration is required, an open heater (at atmospheric pressure or lower) may be combined with a scrap-iron deactivator to remove the residual oxygen. This has been found economical in some cases where the load is not excessive. The scrap-iron may be placed in the bottom of the heater. In any case it is very important to determine how much residual oxygen is permissible, as this and the volume of water to be handled will determine the most economical type of apparatus for the purpose.

For protection of boilers the residual oxygen need not be under one cubic centimeter per liter under ordinary conditions where steel economizers *are not used*. Corrosion becomes so much more active at the temperatures found in economizers that it is important in such cases to maintain the oxygen constantly under 0.2 cubic centimeters per liter. When the temperature of the water does not exceed 180 degrees F., as in the hot-water supply for buildings, more oxygen may be present without appreciable corrosion.

We have found that the rate of corrosion becomes less after a time at temperatures under 180 degrees, under some conditions, due to the formation of a protective film or scale consisting of

iron hydroxids, silica and calcium carbonate. With some waters this scale protection is so effective that no serious trouble is found in hot-water supply lines when the water enters the heater saturated with oxygen; whereas, with other waters, the natural scale-forming constituents are insufficient to afford much protection, hence in such cases it is necessary, if rusting is to be stopped, to lower the free oxygen concentration. In each case there seems to be a certain point below which there is little advantage in reducing the oxygen. This point varies with the temperature of the water, and the rate at which a protective film of scale is deposited. The structure of this film also has considerable influence. This may be controlled to a considerable degree by water treatment. This condition may be due to the establishment of a certain equilibrium between corrosion and the formation of a permanent protective film. However this may be, these films certainly play an important part in regulating the rate of corrosion. It has been well established by operation of many of these de-aërating plants for periods of two years and more that with a residual oxygen under 0.3 cubic centimeter per liter practically no corrosion will occur at 160 degrees F., and even more oxygen may be present under certain conditions without serious trouble. For instance, hot-water pipes last three or four times as long with raw water from the Great Lakes as with New York City water with the same oxygen concentration.

The effect of alkalinity on corrosion is very interesting and is now the subject of a detailed investigation by our Industrial Fellow at the Mellon Institute of Industrial Research. Here, again, the influence of film formation by the flocculation of the colloidal iron has been found to be an important factor in reducing the rate of corrosion, rather than actual alkalinity.

In recent years considerable attention has been given to de-aëration of water in Europe, principally in connection with steam-power plants. Most of these plants have been designed by concerns interested in water treatment for boilers and use the mechanical principle of de-aëration.

The mechanical devices used in Europe for de-aëration are of various design—intermittent or continuous, and operating either at atmospheric pressure or under a vacuum.

The Balcke apparatus (Bochum) for degasifying hot water at atmospheric pressure passes the water, at 212 degrees F., up and down between vertical baffles in a horizontal tank, giving the air an opportunity to escape through a manifold connected into the top of the tank between the baffles. Like most of these devices, this one is designed on the principle of the open feed-water heater, with arrangements to break up the water and cause more thorough separation of the gases. The Balcke Company also makes a mechanical de-aërator, to be connected to a condenser, which may be operated hot or cold. The raw water is sprayed into the separating chamber attached to the main condenser under the same vacuum. The non-condensable gases are drawn through the ejector and through an auxiliary condenser. The water shows a proportionate drop in temperature in passing through the vacuum chamber. Where sufficient exhaust steam is not available this is operated with water at normal temperature under high vacuum.

The Sigmon-Schmidt Söhne apparatus (Hamburg) is another type of de-aërator using baffles which cause a whirling action, which probably causes the air bubbles to coalesce, thus facilitating their removal. A condenser is provided to take care of the steam which passes off with the air when the water is at or near the boiling point, as in the Balcke and the Elliott apparatus.

The Deutsche Sanitätswerke apparatus (Bremen) is designed to coalesce the air by a whirling movement assisted by the entrance of a jet of air into the hot water. One of these plants has been installed in the electric power-plant at Brandenburg and, according to reports, is working successfully.

The Atlas apparatus "No. 2" consists of a chamber in the upper part of which are gratings over which the water drops. The water enters at high speed and falls down on the grating in jets. The air is liberated and rises. The increased air pressure causes the water-level to drop until the float control opens an air-valve. The conditions here are not so good for complete oxygen removal on account of excess pressure in the separating chamber. Other forms of apparatus have been proposed following these principles, but the above are typical of German practice.*

*Les corrosions du fer et leur suppression par le degazage de l'eau. by G. Paris. (In Chimie & Industrie, 1921, v. 6, p. 11.)

G. & J. Weir, Glasgow, and the Metropolitan-Vickers Company, London, make de-aërating apparatus in England, as do the Union Thermique, and Kestner, in France. There seems to be much more diversity of detail in the design of such apparatus in Europe than in America. Definite and reliable results of operation are lacking.

Mr. J. J. Wilson, of the National Tube research laboratory, has designed an interesting method for coalescing the air into large bubbles, which, of course, separate from the water in much less time than in the form of mist. The heated water under low pressure is passed through a close coil of tubing about two or three feet high at moderately high velocity before entering the air-separating chamber. The mist of air which first forms when the pressure is released is coagulated, as it were, into large bubbles which travel on the inside of the coil, the water being forced to the outside of the pipe coil by the centrifugal effect.

It sometimes happens in certain localities that cold water is particularly corrosive to brass or iron pipes. This action may be greatly diminished by extracting 80 to 90 per cent. of the gases. Of course, this must be done under a high vacuum from which the water is usually repumped. The installation put in to protect 300 miles of 30-inch steel water main in the Coolgardie mining district, Western Australia,† is good experience as to what can be accomplished under such conditions. The reports indicate that this plant removes about 80 per cent. of the gases, and that corrosion has thereby been reduced to about one-fourth of the original amount.

A plant has recently been installed at Haddon Hall, Atlantic City, by the Anti-Corrosion Engineering Company, of New York, for de-aërating cold sea-water, the results of which seem to be satisfactory. There will probably be some corrosion from sea-water even when completely de-aërated, especially at high temperature, due to the $MgCl_2$ contents, but some experiments made at the Massachusetts Institute of Technology indicate that even in the presence of $MgCl_2$, or dilute free acid, corrosion is considerably reduced by lowering the oxygen concentration.

†The Coolgardie Water Supply, by P. V. O'Brien and John Parr. (In Minutes of Proceedings of the Institution of Civil Engineers, 1917-1918, pt. 1, v. 205, p. 310.)

As at present there is no commercial piping made which will resist the action of hot sea-water satisfactorily, this experience may prove to be of considerable importance to large hotel operators on the coast.

It is probable that certain types of de-aërating apparatus will be found best adapted for certain purposes, considering efficiency of operation, first cost and cost of operation. The requirements, especially in old plants, differ so widely that the best arrangement can be suggested only after a study of all the factors and existing conditions.

Piping troubles due to corrosion are not confined to wrought-iron or steel, as many in this district will testify. We have found that about the same percentage of protection is obtained with this treatment for brass and zinc. In some localities the need of such protection is very apparent.

Over 150 various kinds of apparatus for de-aërating water have been installed in this country up to the present, the first of these being put in operation in Pittsburgh in 1915. While more work should be done to standardize and simplify this equipment, there is no doubt, from the results so far obtained, that corrosion in closed systems can be controlled economically by these means. This applies particularly to water- and steam-heating systems, and power-plant equipment.

DISCUSSION

Mr. G. M. Goodspeed, *Chairman*:* I am sure Mr Speller's paper has been most interesting and instructive. It is particularly interesting as showing present-day apparatus, as illustrated to us to-night, compared with what Mr. Speller referred to as the original apparatus which was tried out in 1906. This consisted of a piece of five-inch or six-inch pipe filled with steel turnings with the water flowing through it. In all of its simplicity it is remarkable the amount of reduction of corrosion that was accomplished. Of course, as Mr. Speller says, it was not practicable.

Mr. A. E. Blake:† I would like to ask Mr. Speller whether attempts have been made to utilize other metals (or their suboxids) than iron, such as manganese?

Mr. G. M. Goodspeed, *Chairman*: We have with us the Pittsburgh Section of the Master Steam and Hot Water Fitters Association, and we should be very glad to hear from some of them.

Mr. J. B. Walker:‡ Mr. Chairman, as members of the Heating and Ventilating Society, we are very glad to accept the invitation of your Secretary to be present with you this evening. We hesitate in accepting your invitation to take part in the discussion, as the subject is a little heavy for us. It is one with which we are not intimately acquainted, and for that very reason we came to find out a little more about it, and I can assure you we are taking away quite a little more than we brought.

I am sure I voice the sentiment of our Society members when I say that it is a pleasure to be with you. We congratulate you upon your showing on the number present and the interest taken, as indicated by the paper presented and the discussion. Your method of having the papers and the formal discussion prepared in advance strikes us as being admirable and conducive to careful-

*Metallurgist, National Tube Co., McKeesport, Pa.

†Pittsburgh Representative, U. G. I. Contracting Co.

‡Treasurer, Master Steam and Hot Water Fitters Association of Allegheny County, Pittsburgh.

preparation and intelligent discussion. It would seem to be in line with what is good procedure for society management.

I would like to add that we also have a claim upon the speaker of the evening as being one of the members of our Society, and while we may admit that he may belong to you to the extent of 50 per cent. of his royal self, we will also contend that we own and are entitled to the remainder.

Mr. J. C. Hobbs:* I would like to ask Mr. Speller what he would recommend for an 8- or 10-room residence.

Mr. E. O. Mueller:† Very recently I was asked, by a man I had known for some years, if I thought that a process that would remove oxygen from water would be a commercial success, and I said I certainly thought it would. I did not know very much about the subject, but was informed that he had in mind a process which involves a considerably smaller expenditure than the apparatus now on the market. It consists of nothing more than a chemical treatment of the water itself and necessitates no cumbersome or expensive apparatus. It supposedly can be used with equal success in a boiler plant, a locomotive or a house-heating system. The name of the company is the Sterling Equipment and Supply Company, of Philadelphia, and, as I recall, they have a local office in the Empire Building. I was told that they expected to place this treatment on the market within a few weeks, and it is intended to advertise it nationally.

Mr. A. E. Blake: Mr. J. C. Ballantyne, formerly of the Mellon Institute of Industrial Research, was working on a problem of keeping pressed-steel radiators rust proof. He partially solved the problem by the use of what are called "passivating" agents, by which he attempted to render the steel or the iron passive by the use of certain compounds, most of them strongly oxidizing. For instance, strong nitric acid will render steel passive so that for quite a time it will not be corroded by ordinary water. He introduced into the radiators balls of gypsum con-

*Manager, Allegheny County Steam Heating Co., Pittsburgh.
†Secretary, Buell, Scheib, Mueller, Inc., Pittsburgh.

taining small quantities of potassium bichromate, and found that the corrosion was very much cut down. Knowing of his work, I was called on a couple of years later to prevent corrosion through pinholes in nickel-plated, sand-blasted cast-iron (stove-plate iron) —very corrosive material. The superintendent of the foundry thought that the oven of a stove would look very much better if it were nickel plated. It was very pretty after being sand-blasted and plated, but it would corrode in the atmosphere through pinholes in the nickel plate, in spite of anything he could do. He came to me for aid, and I made a 0.6 per cent. solution of potassium bichromate and soaked a few of those plates in it. He put some of them on the roof and others under eaves, and gave some of them to the foreman of the plating room to be tested. Those which had had the treatment developed no pinhole rust whatever, even when the plater grew desperate and put them in salt water. I do not see how that could be taken much into account with the kind of systems which have been dealt with here to-night, but in some places "passivators" might have quite a use.

Mr. J. B. Crane:* Mr. Speller describes the development of apparatus for removing free oxygen from water and mentions the fact that to prevent corrosion of pipes carrying hot water, and corrosion in steel-tube economizers, it is necessary to remove the air.

In the last few years there have been several boilers constructed with a form of economizer called a preheater, inasmuch as the water is introduced into a separate drum or compartment in one of the other drums and the water passes through tubes connecting such drum with the main part of the boiler without the long travel and the great number of tubes that exists in economizer work.

In some of these, corrosion has occurred which takes the form of pitting beginning about the center of the lower drum and becoming more pronounced towards the top of the drum and in the lower end of the tubes, and it has been necessary to remove the oxygen from the water in a great many of these cases in order to stop this pitting. In other types there has been no corrosion even

*Engineer, George T. Ladd Co., Pittsburgh.

when the water contains considerable free oxygen, and in investigating the two cases it has been found that in those where no corrosion occurs the travel of the water in the rear tubes is about 12 inches per minute; whereas, in those in which corrosion occurs the travel of water in the rear tubes is four to six inches per minute.

The theory we have developed in connection with this action is that the free oxygen in the water collects on the upper part of the drums during periods of low steaming and, when the boiler is again actively operated, the travel of the water in the rear tubes is so slow that it does not remove the bubbles of oxygen from the point of the drum where they have collected; whereas, in the second case, when the water moves at 12 inches per minute, or faster, there is enough suction to remove such particles of gas as have collected on the upper part of the drum. This may or may not be the correct theory for this phenomenon, but, at any rate, we know that corrosion does not occur in the latter case and does in the former, and we would like to ask Mr. Speller if such a theory is tenable.

Mr. M. F. Newman:* The information given by Mr. Speller is of particular value, inasmuch as it starts from clearly demonstrated facts regarding the relation of oxygen in water to corrosion.

The de-aëration of water for general service is unquestionably the corrective remedy for corrosion in cold- and hot-water lines, but the conditions applying to water in service lines differ very materially from the conditions that are encountered in the use of water for the generation of steam. Water may be corrosive in the cold, or when heated in a closed system to temperatures lower than the boiling point, but if heated to 200 degrees F. in a vented open feed-water heater and then used for the evaporation of steam in the boiler, no corrosion may be in evidence. The temperature of 200 degrees F., or higher, in the open heater for boiler feed-water apparently removes the oxygen to an extent sufficient in certain specific cases to prevent active corrosion in the boiler.

*Manager, Water Purifying Department, Wm. B. Scaife & Sons Co., Pittsburgh.

Where the temperature of the feed-water is below 180 degrees F., and the boilers are operated intermittently, there have been some well-defined cases of corrosion traceable to the oxygen carried in the feed-water. Using properly softened water through an open heater where a temperature of 200 degrees or higher is attained, practically inhibits the corrosive action of the residual oxygen in economizers and boilers if there is no contamination from water containing magnesium chlorid or magnesium sulphate exceeding the equivalent of the alkalinity of the softened water make-up. Surface condensers presumably do not admit any of the condensing water into the condensate; but, unfortunately, this is not generally the case and leakage is at times greater than can be neutralized by an alkaline softened make-up. When distilled water make-up is used, any condenser leakage of water containing magnesium salts becomes more of a menace.

The removal of oxygen alone from a boiler feed-water will not completely inhibit corrosion from free acids in the water, such as sulphuric acid or hydrochloric acid, nor will it insure against corrosion from the dissociation of magnesium chlorid or magnesium sulphate, for under the conditions of temperature, pressure, and concentrations occurring within the boiler, corrosive action can take place directly from the action of the free acid or the acid radicals of the disassociated magnesium salts in the absence of dissolved oxygen.

In those cases where boilers are fed with injectors from cold-water tanks, the water ordinarily has a large content of oxygen and no liberation occurs until after the water is in the boiler. If the boiler is clean, very active corrosion may occur, and in such cases the alkalinity of the water does not seem to have any inhibiting effect. Corrosion from oxygen will occur under such conditions from softened water having an alkalinity due to sodium carbonate and calcium carbonate, or calcium carbonate, sodium carbonate and sodium hydroxid. If the boiler is scaled, corrosion is noticeably less and in some cases there is none.

A peculiar phenomenon is that the corrosive action does not occur in all cases of cold-water feeding, and it seems to be less noticeable—and, in fact, in some cases entirely absent—where the organic content of the water is relatively high and where labora-

tory tests indicate a high consumption of oxygen by dissolved organic matter.

A case in point is where water, having an analysis as follows, does not scale or corrode:

	Parts per million
Volatile and organic matter	32.3
Silica	9.4
Calcium carbonate	30.6
Magnesium hydroxid	8.8
Sodium carbonate	14.5
Sodium sulphate	200.4
Sodium chlorid	55.7
Sodium hydroxid	4.1
Alkalinity	76.5

Laboratory tests showed a high consumption of oxygen.

This water when boiled and reduced to two-thirds the original volume in the laboratory remained clear and gave no precipitate, notwithstanding the fact that the calcium and magnesium content of the water was about twice as great as is ordinarily present when correctly softened. The high solubility of the calcium carbonate and magnesium hydroxid in this case can be attributed to the large amount of soluble organic matter present. The organic matter also tends to prevent after precipitation.

In another case, there is active corrosion with practically no scale formation with water much lower in dissolved organic matter, having an analysis as follows:

	Parts per million
Volatile and organic matter	6.0
Silica	11.0
Calcium carbonate	12.8
Magnesium hydroxid	4.9
Sodium carbonate	22.4
Sodium sulphate	510.0
Sodium chlorid	34.0
Sodium hydroxid	20.4
Alkalinity	68.0

It seems a fair assumption that the reducing action of the

organic matter and the probable formation of a film of organic substances on the metal accounts for the absence of corrosion in the first case, and that the low organic content in the second case was insufficient to reduce the oxygen to the degree necessary to arrest corrosion.

In three laboratory tests on steel strips submerged in glass beakers exposed to the light, the same corrosive effect was indicated in distilled water, in filtered water from the Allegheny River showing an alkalinity of 22 parts per million, and in softened water having an alkalinity of 76.6 parts per million as calcium carbonate made up of:

	Parts per million
Calcium carbonate	20
Sodium carbonate	25
Sodium hydroxid	14
Magnesium hydroxid	9

These tests indicated very clearly that merely to have a water alkaline is not sufficient to prevent corrosion.

Filtered water from which the iron has been removed and in which the organic substances have been reduced has a noticeably higher rate of corrosion—particularly in hot-water piping—than unfiltered water, and, in an instance in which a filtered river water was in use, no serious corrosion was occurring in the cold-water lines, but very destructive corrosion occurred in the hot-water piping in residences and buildings. The water was treated with lime and ferrous sulphate before filtering. The analytical data showed the following:

	Parts per million
Calcium carbonate	44.2
Calcium sulphate	119.0
Magnesium carbonate	5.8
Alkalinity	51.0

With dissolved oxygen in cold water, 11.7 parts per million equals 8.2 cubic centimeters per liter, while, with dissolved oxygen in warm water, 3.0 parts per million equals 2.1 cubic centimeters per liter.

The corrosive action of magnesium chlorid as determined in laboratory tests can scarcely be accepted as applying to conditions

encountered in economizers and boilers. The reaction of magnesium chlorid under high temperature and pressure is not dependent on the presence of oxygen for the formation of magnesium hydroxid and hydrochloric acid. In those cases where the alkalinity due to carbonates or hydroxids is insufficient to react with the total magnesium content of the water, a corrosive action will occur, and in some cases in surface-condensing plants the condenser leakage at times exceeds the reactive value of the alkalinity of the make-up water. In such cases, corrosive effects will be noted in economizers and also in boilers. Alkalinity due to calcium carbonate is not adequate to give the needed protection against magnesium chlorid on account of the possible formation of calcium chlorid and its subsequent decomposition, liberating hydrochloric acid.

In boiler operation, water from natural sources, unsoftened and containing magnesium chlorid, causes corrosion even though after heating it may have an alkalinity due to calcium carbonate or calcium and magnesium carbonates. The alkalinity due to these substances will not prevent the dissociation of the magnesium chlorid or resultant calcium chlorid.

Magnesium sulphate in a natural water having an alkalinity due to calcium carbonate in excess of the combining equivalent of the magnesium sulphate will, upon the decomposition of the magnesium sulphate, form calcium sulphate, which is neutral and stable, so that corrosion will not result when these reactions take place. There have been well-defined cases of natural waters with low alkalinity and a relatively high content of magnesium sulphate causing both scale and corrosion, and corrosion occurring under a deposit of scale.

When water is properly softened and purified, it contains no unstable magnesium salts and no unstable calcium salts. The alkalinity due to sodium carbonate and sodium hydroxid is sufficient to prevent the formation of corrosive acids, and in some cases the reaction of the sodium carbonate and sodium hydroxid on organic substances apparently inhibits the corrosive action of oxygen.

While it is now generally admitted that oxygen is a determining factor in corrosion under certain conditions, it is not so

clearly demonstrated that all of the conditions encountered in the complex concentrations at high temperature and high pressure that occur in a steam boiler can be accounted for by the presence or absence of oxygen. The boiler feed-water in modern electric generating stations is in many cases a close approximation to the ideal of distilled water when surface condensers are tight and the make-up supplied from efficiently operated evaporators. In plants of this type, oxygen is, of course, a great factor and perhaps the determining factor in corrosion when the water in the boiler constantly approximates distilled water. However, the evaporation of steam from what is practically distilled water is materially different from many of the conditions that pertain to steam generation in industrial boiler plants where the feed-water is made up of varying percentages of water from natural sources, or such water softened and purified. These varying conditions with reference to the substances in solution in the feed-water introduce factors that make it extremely difficult to account for corrosion or its inhibition from any single cause for all cases. Water from natural sources can be roughly classified as alkaline, neutral, or acid, but such a classification would have to be further subdivided to cover the many variable groups of substances in solution. The ultimate effect from the various impurities in water when highly concentrated under the conditions of temperature and pressure in boilers produces many baffling effects not easy to trace accurately.

In boilers there is perhaps in many cases a protective film of indefinite composition that arrests corrosion after the elimination of oxygen to the extent obtained with a temperature of 180 degrees F., or higher, in a vented open heater. Softened feed-water with proper alkalinity to stabilize the residual calcium and magnesium against precipitation in the heater and feed lines will, after concentration in the boiler, precipitate calcium carbonate and magnesium hydroxid. These precipitates, in addition to the concentration of certain forms of organic matter, under certain conditions tend to deposit a protective film. The conditions under which such a film is formed are gradually developed in carefully operated boilers using softened feed-water for make-up or for 100 per cent. feed. When the boiler is emptied, this film is similar to a coating of whitewash and is easily rubbed through with the

finger or washed off with a hose. There are some cases, however, where such a film does not form in boilers operating with softened water and the metal is apparently bare, and in some such cases it was claimed that no corrosion existed. Such a result is possibly due to the effect of the concentration of soluble organic substances producing a complex emulsion that provides a moving or living film, which either absorbs oxygen or produces a passive condition by contact with the surface of the metal.

The bibliography of the corrosion of iron and steel indicates that much remains to be determined from actual operating conditions, particularly with relation to the use of water in steam generation where the feed-water is not essentially distilled water. Thus far, with laboratory experiments made mostly on special solutions, there have not been sufficient data accumulated from the actual working conditions to warrant the issuance of any definite statement about corrosion in boilers, attributing it to a specific cause.

MR. ROBERT HUGHES:* I do not feel that I can add anything, for it seems to me that Mr. Speller has covered the subject very well. I might, however, mention my practical experience with water deactivation.

I installed a de-aërating apparatus on the domestic hot water in our Passayunk Plant. This was manufactured by the Anti-Corrosion Engineering Company. It has been in continuous operation since October, 1920, and furnishes deactivated hot water to approximately 500 residences. For my own information I installed a number of lengths of black steel pipe in this hot-water service, and just recently removed one length which had been carrying hot water continuously for over a period of 27 months, and the pipe was in as good condition as the day it was installed. During this period the oxygen content of the water passing out to the system averaged 0.5 cubic centimeter per liter, and the average temperature of the water delivered to the operation was 175 degrees. I might also mention that in three months the rust accumulation had cleared itself from the pipes considerably; so much so that the pressure on the system was reduced from 60 to 35 pounds, which was the normal pressure when the pipes were new.

*Chief Engineer, Board of Directors of City Trusts, Philadelphia.

In addition to the above I have installed the metal-plate type of deactivator in three office buildings with equally as good results, both as to the improved circulation and the elimination of the oxygen.

MR. W. S. ELLIOTT:* Mr. Speller has presented a very complete description of the means employed for separating dissolved gases from water. The experiments we have made confirm the result obtained from the Speller and Walker experiments, which is that temperature, time, velocity and other factors being constant, the extent of corrosion is approximately proportional to the amount of free oxygen contained in the water in contact with metal surfaces.

Many attempts have been made to separate dissolved gases from liquids (as evidenced by the patents in this and other countries) with more or less success, but it appears that Mr. Speller was the first to succeed in reducing the oxygen content to a point low enough to reduce corrosion from that cause to a safe limit when applied intelligently.

Mr. Speller has referred to the development of the art in Europe, and has described several European systems, but he has not submitted data showing the degree of separation by the employment of such systems. There seem to be very little, if any, reliable data available as to the efficiency not only of the types mentioned, but of other types in which attempts have been made to degasify liquids.

As corrosion is substantially proportional to the amount of oxygen carried in the liquid under similar temperature conditions, etc., any device that will reduce the oxygen content is a step in the right direction. The real solution of the problem, however, is a system of treatment which will continuously deliver oxygen-free water. In addition, such a system must be provided with means for control of temperatures and pressures, as well as means for making a continuous record of the degree of oxygen removal.

*President, Elliott Co., Pittsburgh.

The several types of Elliott de-aërators all employ the same fundamental principle—that of changing the phase of a definite percentage of the liquid to an extent sufficient to release and separate substantially all the dissolved gases by the application of a minimum amount of heat under proper pressure conditions. The apparatus described by Mr. Speller performs its function by maintaining a positive difference in temperature and pressure between the raw water immediately before it enters the separating chamber and the temperature and pressure in that chamber. As long as a definite difference in temperature and pressure is maintained, the difference being dependent upon the final temperature required, the results can be predicted with extreme accuracy. A record of these temperatures is necessary as a check. This is obtained by the employment of recording thermometers, one placed in the raw-water line immediately before the separator inlet valve, and the other placed within the separator. The records made enable the management to check up daily the degree of separation indicated by the difference in temperature on the two charts. The apparatus can deliver air-free water at any temperature usually employed in hot-water lines, and plants are now in operation delivering water in some cases as low as 130 degrees F., and in others 212 degrees F., and above, with an equal degree of separation.

Mr. L. W. Heller:* At the Colfax station of the Duquesne Light Company mechanical de-aëration is effectively accomplished with the usual power-plant apparatus. The installed equipment permits of air removal with economic operation of main and of auxiliary steam-driven equipment, together with maintenance of good heat balance.

The features of design and lay-out have been previously published, and for the engineer who is interested in this subject reference may be made to the papers read by Mr. C. W. E. Clarke, "Heat Balance in Steam Power Plants," presented at the December, 1921, meeting of the American Society of Mechanical Engineers, and "Boiler Room Performance and Practice of Colfax Station, Duquesne Light Company," May, 1922, meeting of the

*Assistant Superintendent, Duquesne Light Co., Pittsburgh.

American Society of Mechanical Engineers, and to the discussion by Mr. J. M. Graves, "The Power Stations of Duquesne Light Company," published in the *Electric Journal,* May, 1921. Sufficient illustrations are shown in the above articles to indicate the relation of the various apparatus and water flow diagram.

No economizers are installed at Colfax. While the minimum oxygen prescribed for economizer plants is not required at this station, observations indicate that the oxygen value must be maintained below 0.50 cubic centimeter per liter, particularly since this plant is operating with 100 per cent. distilled water for boiler feed-water supply.

Summarizing the results—the condensate from the main unit is effectively de-aërated to values ranging not in excess of 0.05 cubic centimeter per liter, accomplished in surface condensers of 50,000 square feet of surface, operating under 29 inches of vacuum.

The condensate remains in a closed system until it is utilized as injection water for the barometric condensers. At this point the make-up boiler feed supply is added, consisting of evaporator distillate and stored distilled water. A slight increase in dissolved oxygen is due to this addition of make-up, which contains a greater oxygen content than the main unit condensate. The boiler feed-water is heated by condensing the exhaust steam from the house turbine generating unit, plus other steam-driven auxiliaries used in the station, with a resultant temperature in excess of 200 degrees F.

The main unit condensate represents 98.5 per cent. of the boiler feed supply. The quality of this water, together with the 1.5 per cent. make-up, which is obtained from low-pressure evaporators from which distilled water is furnished, exceeds in purity commercial distilled water.

MR. F. N. SPELLER: I would like to ask if any attempt was made to reduce the oxygen content in the air over the storage tanks.

MR. MAX HECHT:* The original designs indicated the use

*Chemist, Duquesne Light Co, Pittsburgh.

of a layer of cork over the water to avoid the reabsorption of air. The cork was not applied, however, due to mechanical difficulties which would have resulted.

The only good method which appears to me to be satisfactory is to put a one-inch layer of oil on the surface of the water. However, I would not recommend this at all, due to the danger of getting oil into the boilers.

The amount of make-up required from the storage system is so small that we do not make any attempt to eliminate the absorption of air from this water until it is desired for service. It is then pumped to the head tank, the water from which serves as injection water to the barometric condenser, at which time the air is removed as it passes down the tail-pipe of the condenser.

Mr. F. N. Speller: With regard to the question of rendering iron passive, brought up by Mr. Blake—this seems to be due to the formation of an oxid film, but in the absence of the "passivator" this soon breaks down, especially when heated. Such attempts to control corrosion so far have not been effective. Zinc has been used to some extent as a substitute for iron, but, of course, is much more expensive and is not so effective or permanent.

We have not heard of the process referred to by Mr. E. O. Mueller, but I should not be surprised if several "new" schemes were offered in the near future for removing oxygen from water or protecting the metal under water, as the problem is a very practical one and the principles involved are well understood. However, it should be remembered that many factors are involved in corrosion, and that experience counts for a good deal in the practical solution of these problems. It is only fair to state, as the question has been asked, that the Anti-Corrosion Engineering Company, of New York, and the Elliott Company, of Pittsburgh, are the pioneers in this work, each having developed and installed a practical form of apparatus for this purpose.

Mr. Crane asks as to whether a difference of from 4 to 12 inches per minute would account for a material difference in corrosion. This depends on other factors. If the pressure is over 10 pounds above that of the atmosphere, there will be no separation of gas to speak of under 180 degrees F. The difference in

velocity mentioned does not seem to be a material factor, but, at pressures low enough to permit of a large proportion of gaseous separation, might have the effect suggested by Mr. Crane.

Mr. Hobbs asks as to protection of pipe in a medium-sized residence. Any form of deactivator would probably be rather expensive, although several have been installed in residences. We have been doing some work on this problem and expect to offer some suggestions before long. At present, deactivators cost from $300 upwards and the metal in the deactivating tanks has to be replaced every two or three years.

The observations made by Mr. Newman, as to reactions which might take place in a boiler resulting in some corrosion in the absence of oxygen, are very pertinent. Nevertheless, it should be remembered that oxygen apparently acts as a depolarizer and, as such, will accelerate the action of acid when present. The remedy for $MgCl_2$ when present is to treat your water so that it will be distinctly alkaline at all times, and then take care of the oxygen.

We were advised of a case in a power-plant in Connecticut where severe corrosion occurred in boiler-feed lines between the heater and the boiler. This was reduced to about 30 per cent. of the rate on raw water by placing expanded sheet steel in the bottom of the feed-water heater. On analyzing the situation still further, $MgCl_2$ was found in the boiler water. When the water was treated, as well as deoxygenated, corrosion was cut down to five per cent. of what it was with the raw water.

PULVERIZED FUEL FOR LARGE BOILERS

By J. C. Hobbs* and L. W. Heller†

INTRODUCTION

This paper covers an investigation into the possibilities of burning coal, in pulverized form, in furnaces designed to produce heat for generating steam. The paper is divided into two main parts. The first part deals with the tests and results of an experimental installation; the second part, with the general analysis of the problem, including the solution which now appears most logical.

Since the investigation was first started, many interesting and valuable developments have been made in the art. The results already attained have been so satisfactory that large installations are being made not only in Pittsburgh, but in many other places.

Coal has been burned in powdered form for many years. It is not the purpose of this paper to give a history of powdered coal development, but rather to furnish a statement of the results obtained from an installation designed for the express purpose of determining the value of this method of combustion when applied to the large-sized boilers used in modern central stations.

While the concentration of generating equipment in large plants has very greatly reduced the coal consumption per kilowatt-hour, the decreased cost, the ease with which electrical energy can be obtained, etc., have resulted in such an enormous increase in the use of electricity, that the total coal consumption has also greatly increased.

Pittsburgh, the workshop of the world, uses so much power and burns so much coal that every effort should be made to improve the efficiency and reduce the cost of obtaining a power which is so essential.

Combustion itself is not a new art; and, while certain of the results which will be presented may appear in a new form, no credit is claimed for the performance achieved, except such as is due those who have been diligent in carrying out the details of such an investigation made possible by the size of the organiza-

*Manager, Allegheny County Steam Heating Co., Pittsburgh.
†General Superintendent of Power-Stations, Duquesne Light Co., Pittsburgh.

tion and the policy adopted by its management. At the time this investigation was authorized, it was felt that the art had progressed to such a point that full information was needed in order to insure, against obsolescence, the large investments in power-plants which must be made almost continuously to serve the demands of our community. Complete information can be obtained only by a first-hand investigation. It is not practicable or even possible to report all of the results and conclusions reached in the various studies of the many factors involved. In addition to the great advantage of obtaining definite first-hand information, it was felt that the time had arrived when a contribution in the development work would be justified, and that any further delay in order to "let George do it" at his expense, was a costly policy to pursue for all concerned.

DESCRIPTION OF INSTALLATION

Tests were conducted on a Stirling boiler, type M-30, nominally rated at 822 horse-power, to which was attached a water screen having 180 square feet of heating surface, and an additional nominal rating of 18 horse-power, totaling 840. During the first test, the boiler was equipped with a Babcock & Wilcox superheater having 255 square feet of surface. During later tests this superheater was replaced with a larger one having 1031 square feet of surface. During the first test, the boiler was baffled so as to obtain three effective passes. The later tests were made with a four-pass baffle.

A special furnace was built with a large combustion chamber, and air-cooled walls. The pulverizer or milling plant consisted of one standard six-ton, six-roll Raymond mill, together with exhauster fan, separators, and the usual piping.

The testing equipment consisted of operating coal scales for weighing the coal fed to the pulverizer, water-weighing tanks and scales, and all other miscellaneous gages, manometers, thermometers, pyrometers, and apparatus required to make a complete boiler test.

While not large in rated horse-power, even this boiler represents a comparatively large unit, measured on the developed horse-power basis, its maximum rating being more than 2500 horse-power.

Fig. 1 was drawn to show the general arrangement or assembly of the various component elements.

Fig. 2-4 show the actual installation.

Fig. 5 shows more clearly than the general assembly the details of the three-pass baffle.

Fig. 6 shows the four-pass baffle.

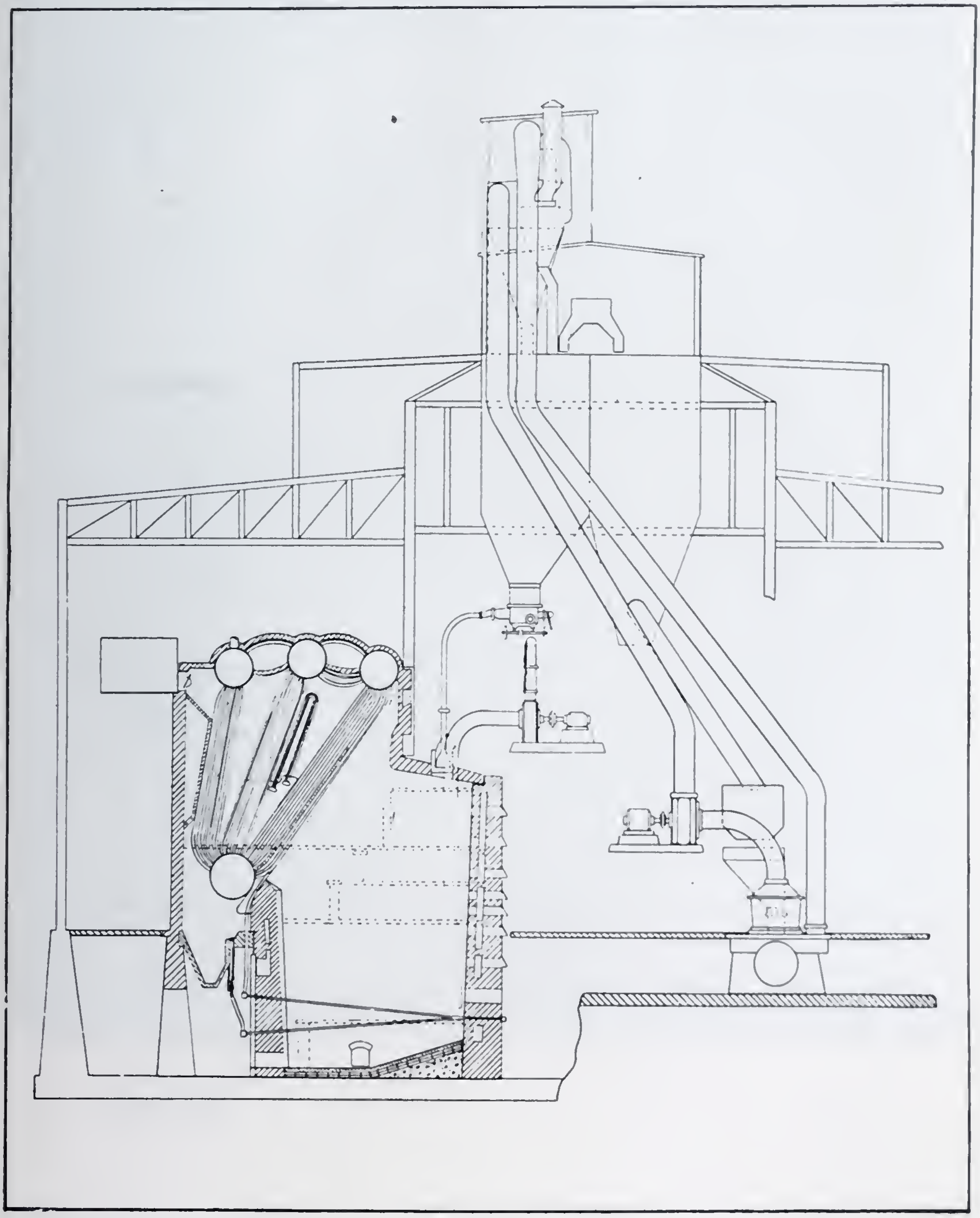

Fig. 1. General Arrangement of Various Component Elements.

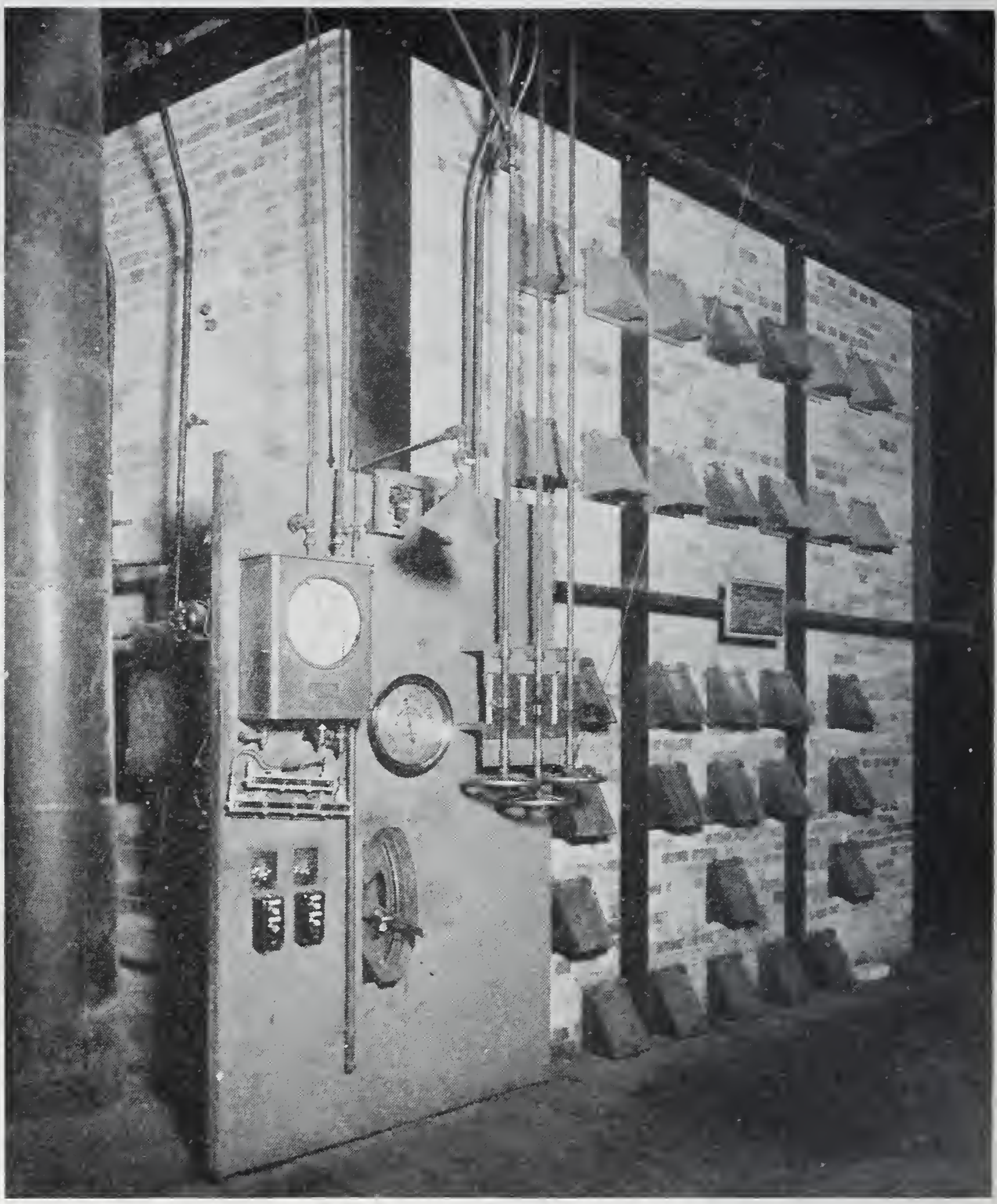

Fig. 2. General View of Boiler Front from Operating Room.

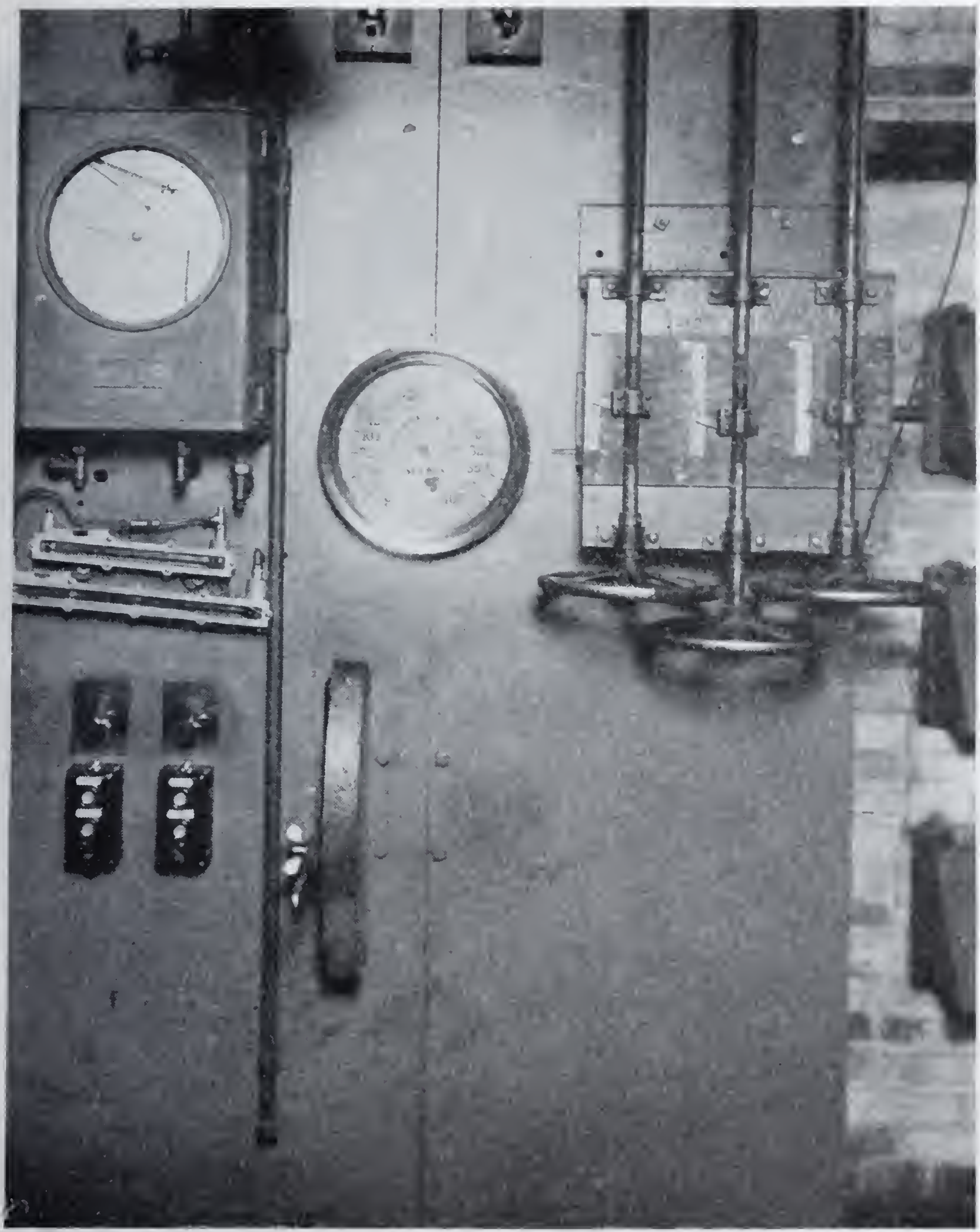

Fig. 3. View of Instrument Board and Controls.

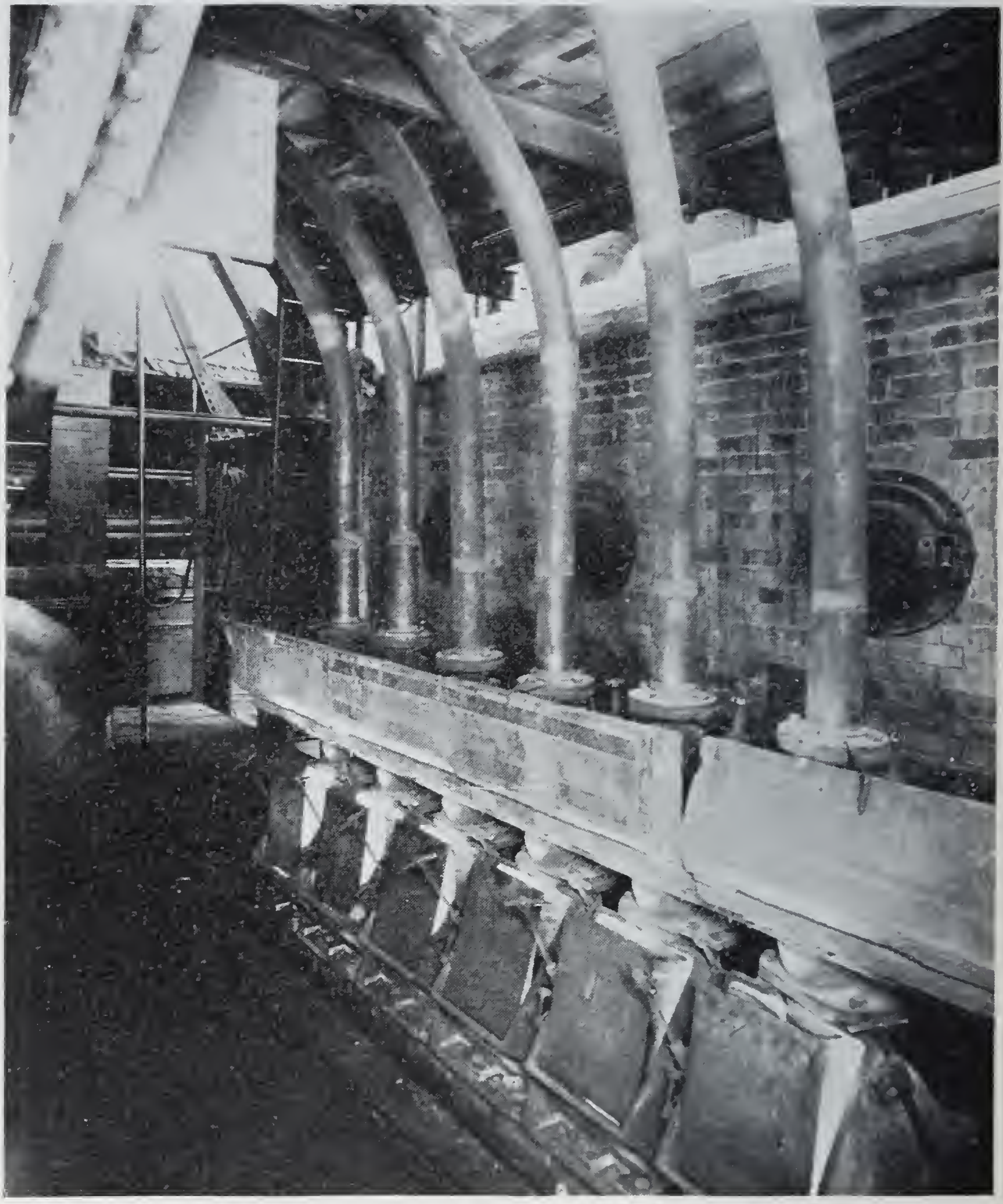

Fig. 4. View of Burners.

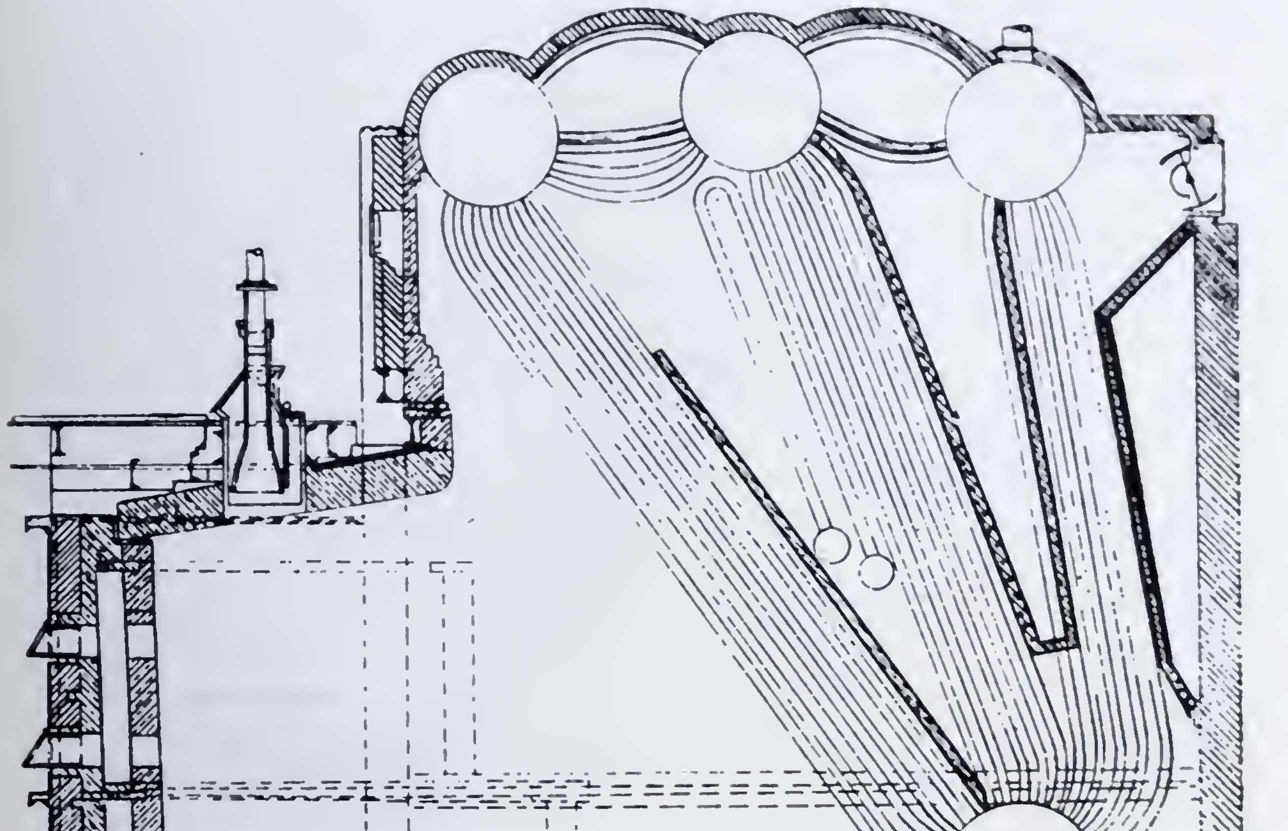

Fig. 5. General Assembly and Arrangement of Three-Pass Baffle.

SCOPE OF INVESTIGATION

The scope of the investigation was made broad to determine the real value of this method of firing when compared with the

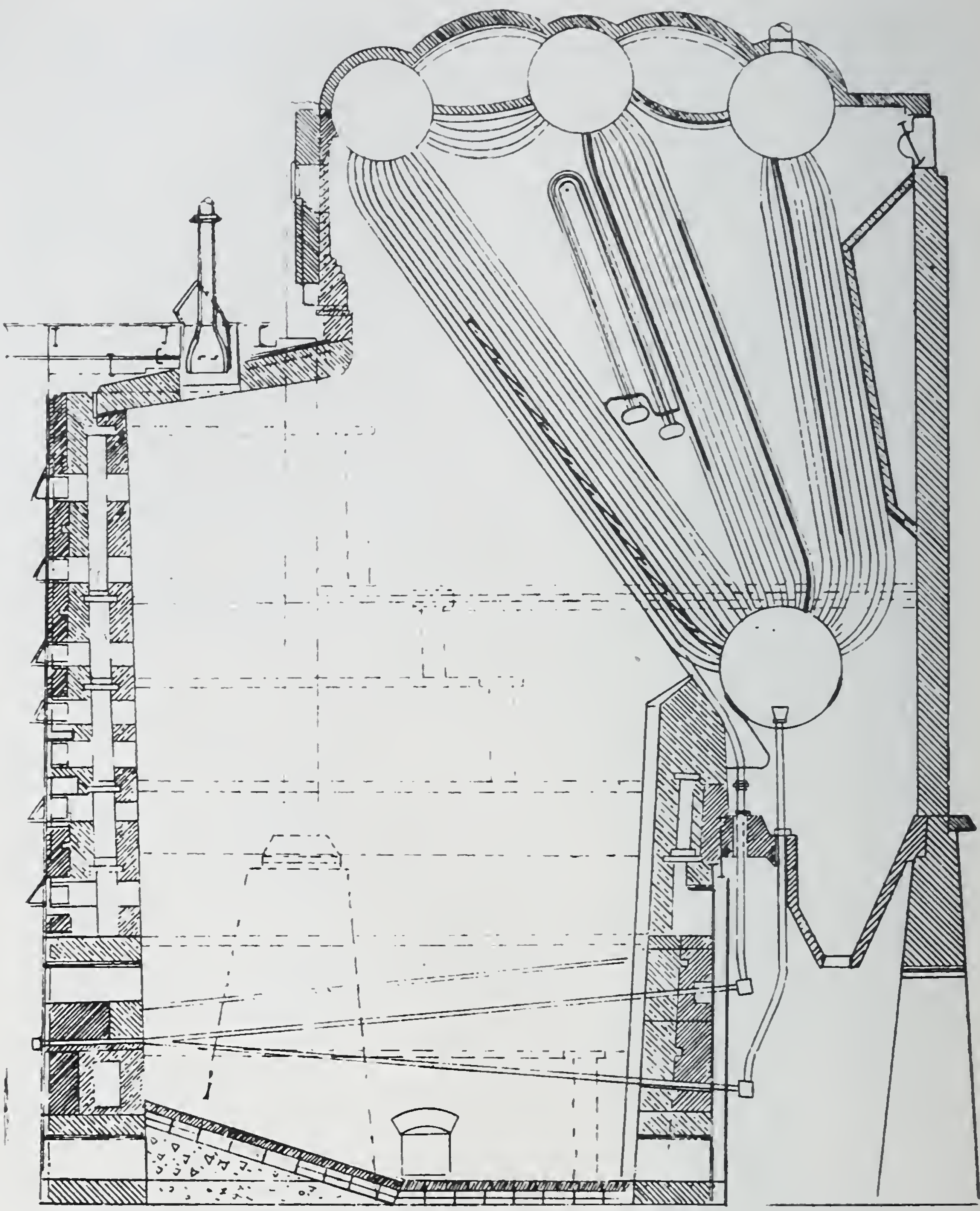

Fig. 6. General Assembly and Arrangement of Four-Pass Baffle.

best standard practice in central stations. Some of the more important factors are:

1. Combustion efficiency.
2. Boiler absorption efficiency.

3. Effect on superheat produced.
4. Capacity of boiler.
5. Banking losses.
6. Capacity of stacks.
7. Flexibility and ease of operation.
8. Time required to put a boiler on the line.
9. Labor required for operating boilers and pulverizing plant.
10. Maintenance costs of the boiler, furnaces, and pulverizing plant.

RESULTS

In order to make it easy to analyze the various factors and the effects produced, the great mass of tabular data has been converted into curves which present the conclusions almost at a glance.

During the investigation, the following changes were made to determine their effect:

1. A change from three- to four-pass baffle was made.
2. The original superheater was replaced with one having more surface.
3. Two different types of pulverized fuel feeders were used.

The original superheater is referred to as "Superheater A", and the latter as "Superheater B"; the original feeders as "Feeders A", and the latter ones as "Feeders B".

Fig. 7-8 show:

1. Variation of boiler and furnace efficiency.
2. Stack temperature.
3. Superheater temperature at the various furnace ratings, expressed in B.t.u. absorbed by the boiler per cubic foot of furnace per hour.

Fig. 9-10 show the relation between CO_2 and:

1. Load of boiler rating.
2. Stack temperature.
3. Superheat.
4. Draft loss.

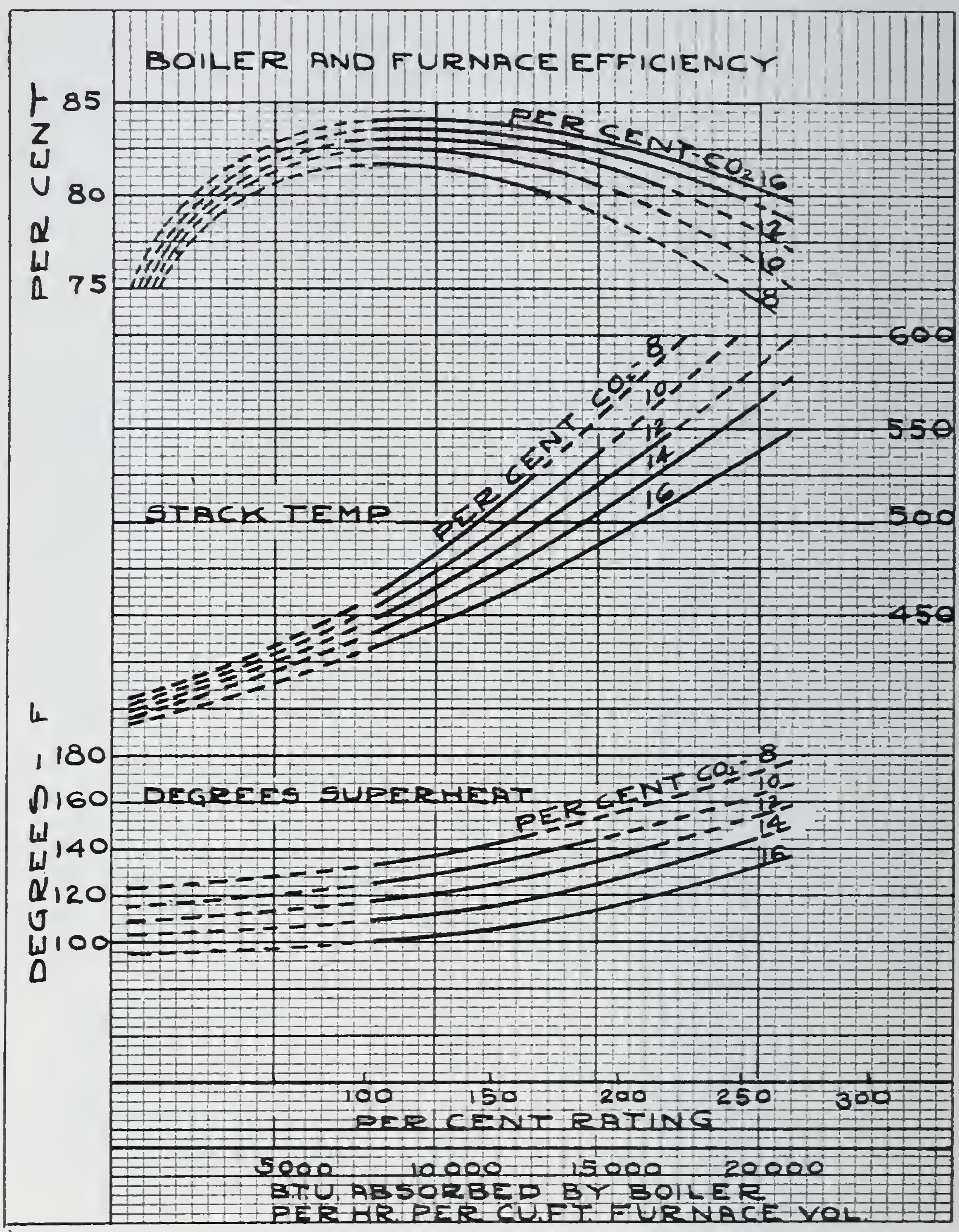

Fig. 7. Results with Four-Pass Baffle.

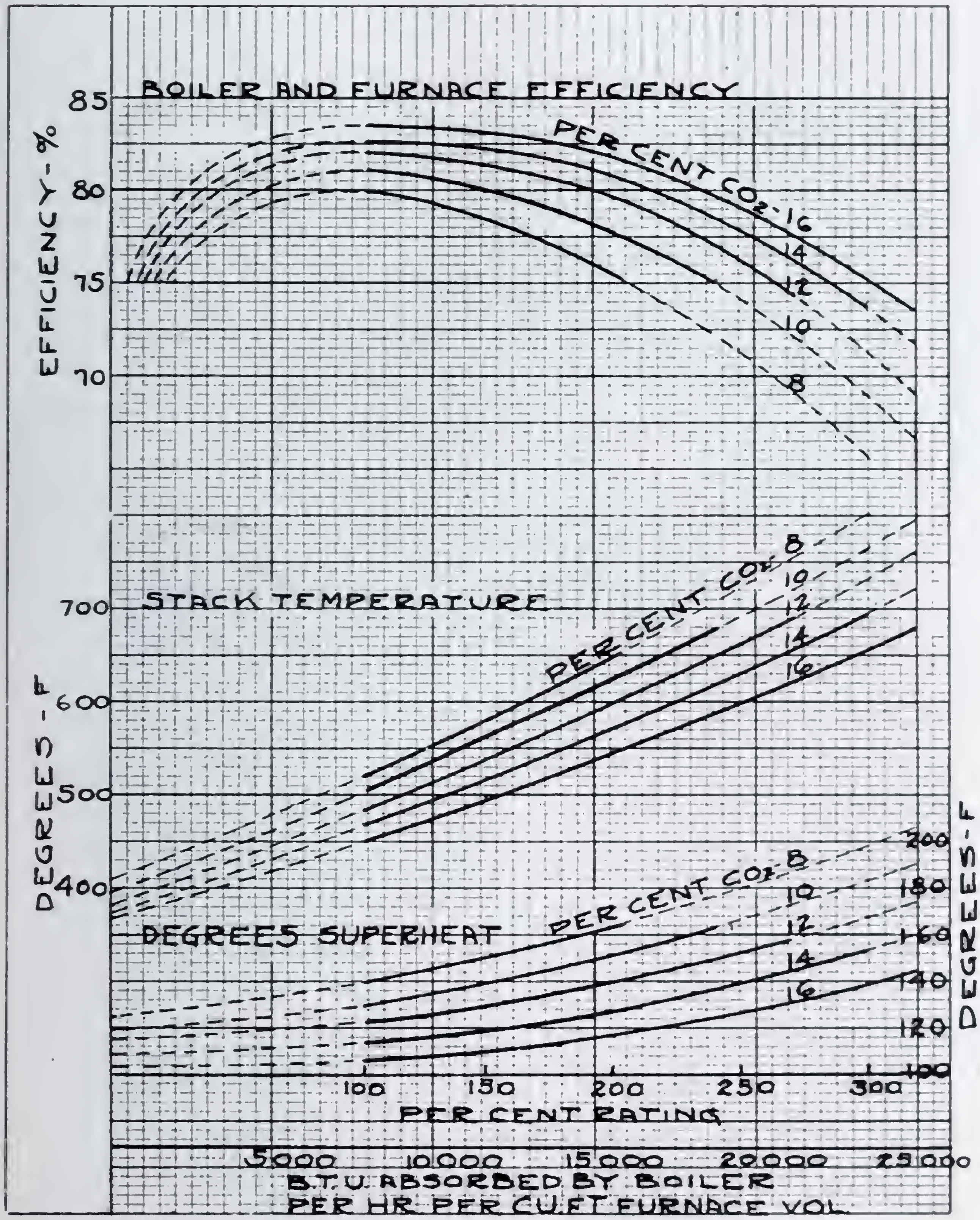

Fig. 8. Results with Three-Pass Baffle.

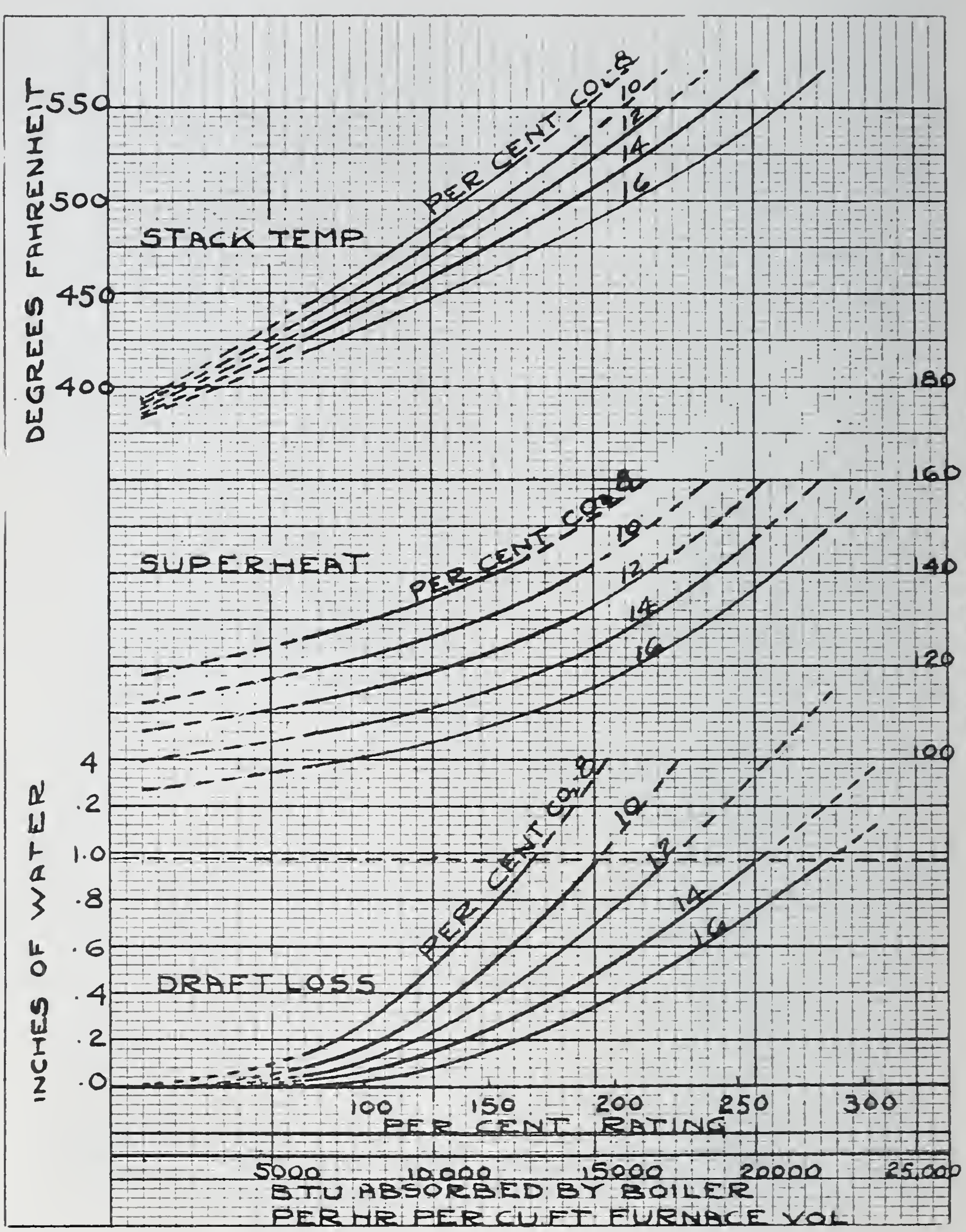

Fig. 9. Results with Four-Pass Baffle.

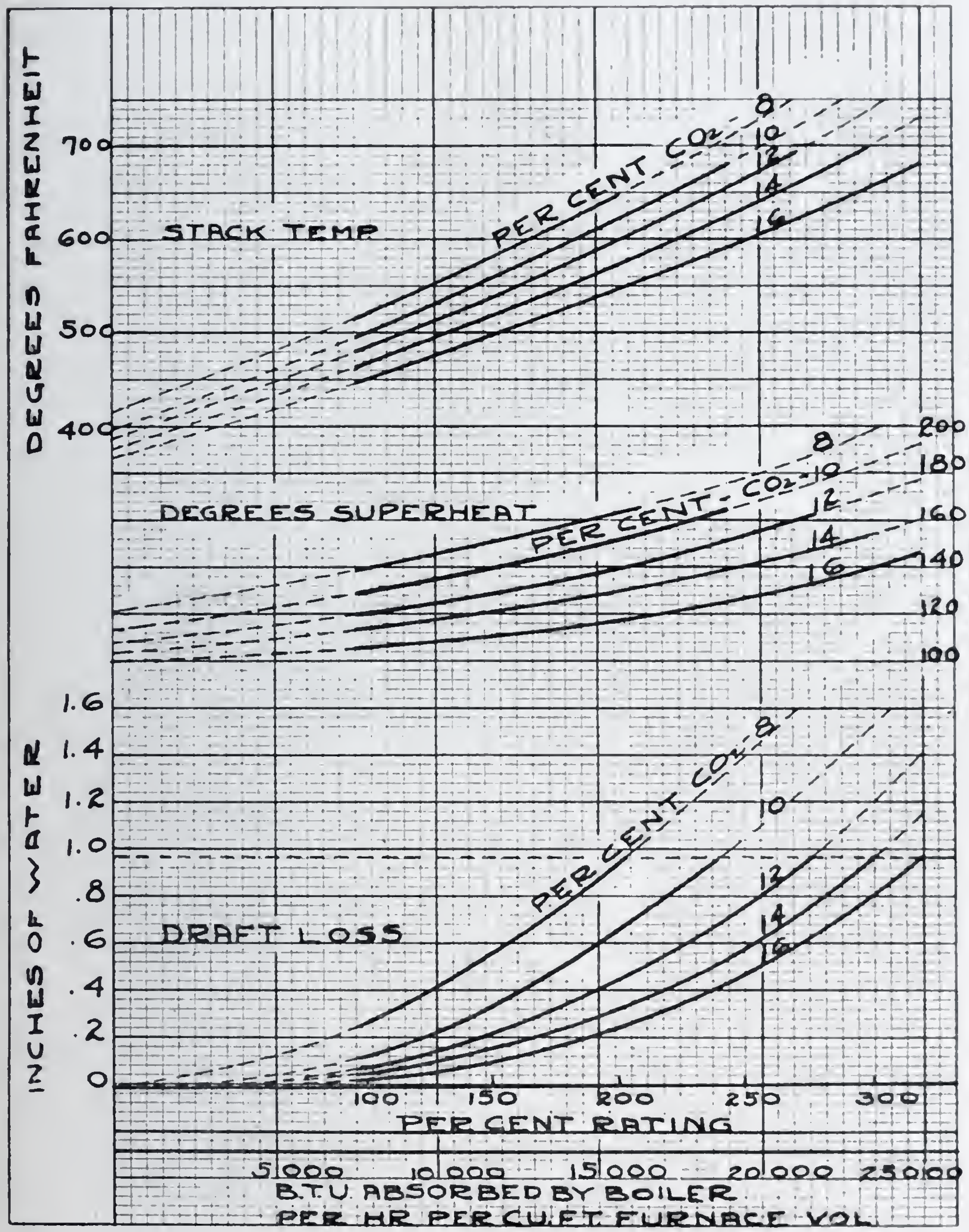

Fig. 10. Results with Three-Pass Baffle.

This curve is one which we have often talked about, but never before had an opportunity to obtain from actual test, it being impossible to determine with the ordinary stoker job the effect of a variation of the CO_2. Other factors vary so much that no definite conclusions could be reached. This curve is particularly interesting because it shows very conclusively that stack temperatures are greatly affected by the percentage of CO_2. The superheat is also affected, and in this connection it should be mentioned that superheaters which are to be installed in powdered-fuel installations, should either be located closer to the furnace or have more heating surface in order to obtain the same amount of superheat in the steam.

The information regarding draft loss is also very striking. It indicates that increased boiler capacities can be obtained with the same stack and baffle arrangement by simply reducing the amount of excess air, which is equivalent to increasing the CO_2. The explanation is simple. The total quantity of gas which must be handled is greatly reduced and the friction loss through the boiler and the stack is varied approximately as the square of the volume of gas. (See Fig. 11-12.)

Many years ago it required some explanation to convince engineers that an increase in stack temperature might be due to an increase in the excess air; but I believe it is now very generally understood that the stack temperature has a tendency to increase with the amount of excess air admitted to the furnace up to the point where the furnace temperature is greatly affected, after which, due to extreme dilution, the final stack temperature is reduced.

Fig. 13 shows an analysis of the power consumption for the entire operation, consisting of pulverizing, separating, transporting, storing and feeding. Some development work towards the reduction of this power has already yielded good results. In making an analysis of power and consumption in connection with the combustion problem, care should be taken to prevent the omission of the various operations required by some of the stoker methods.

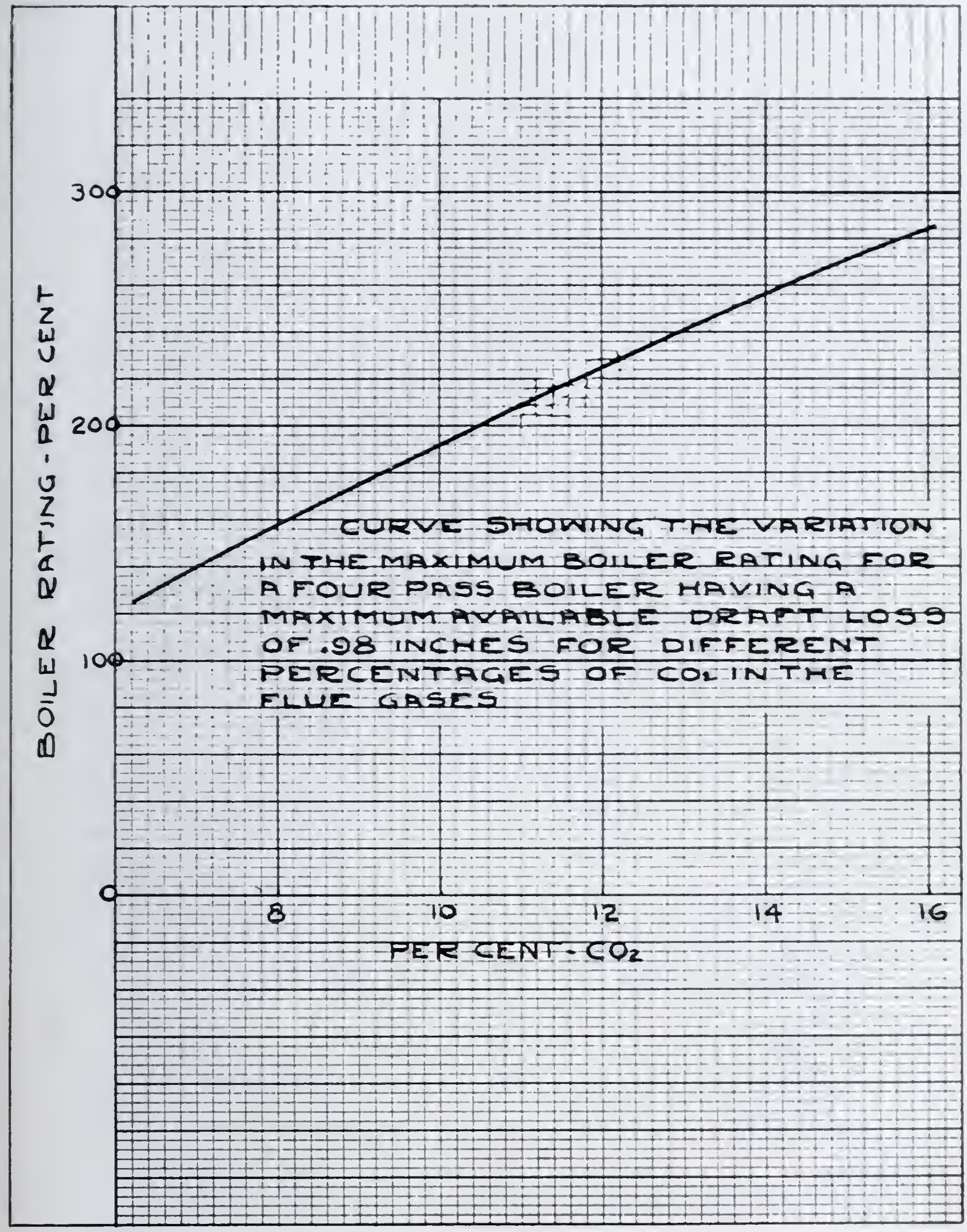

Fig. 11. Results with Four-Pass Baffle.

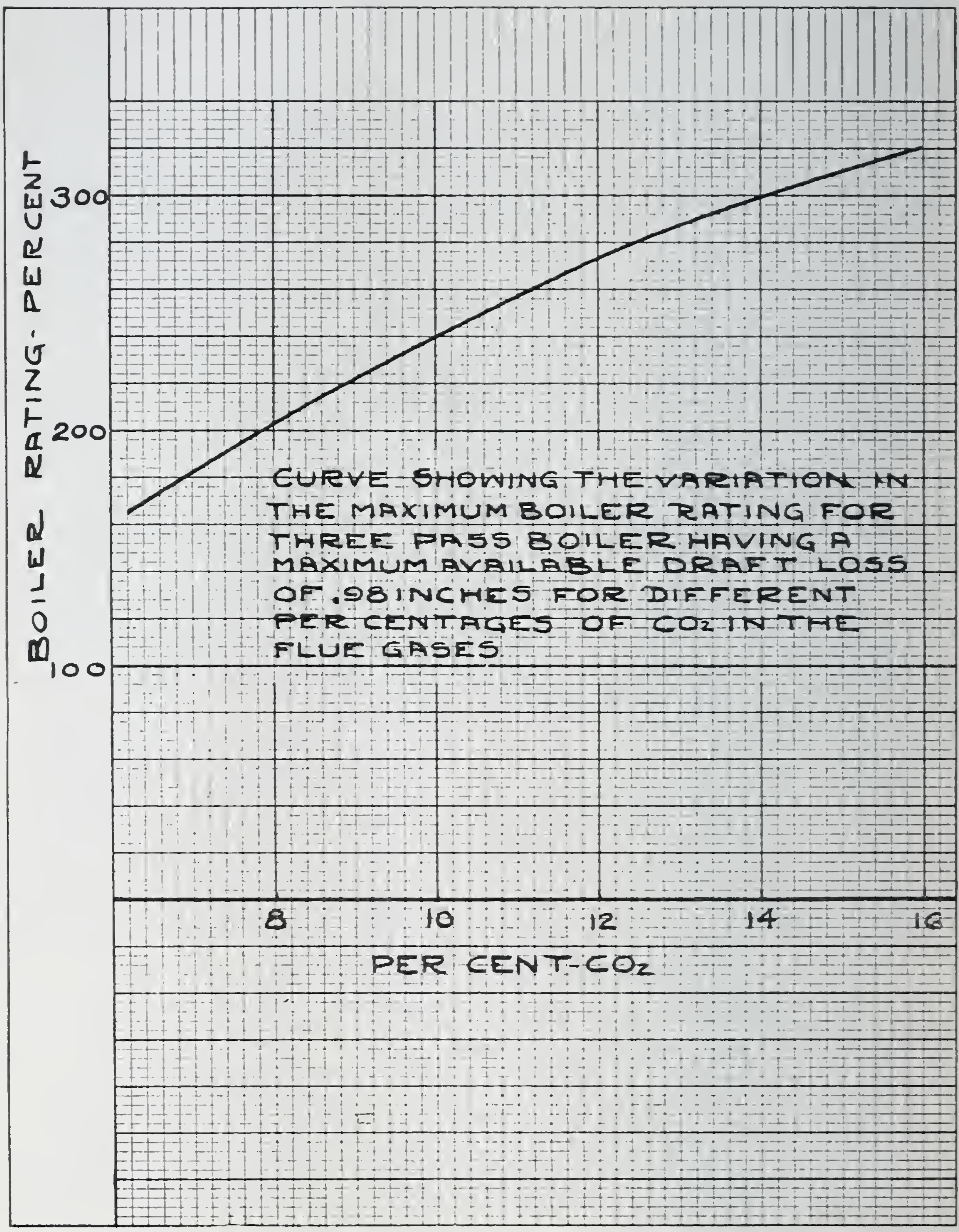

Fig. 12. Results with Three-Pass Baffle.

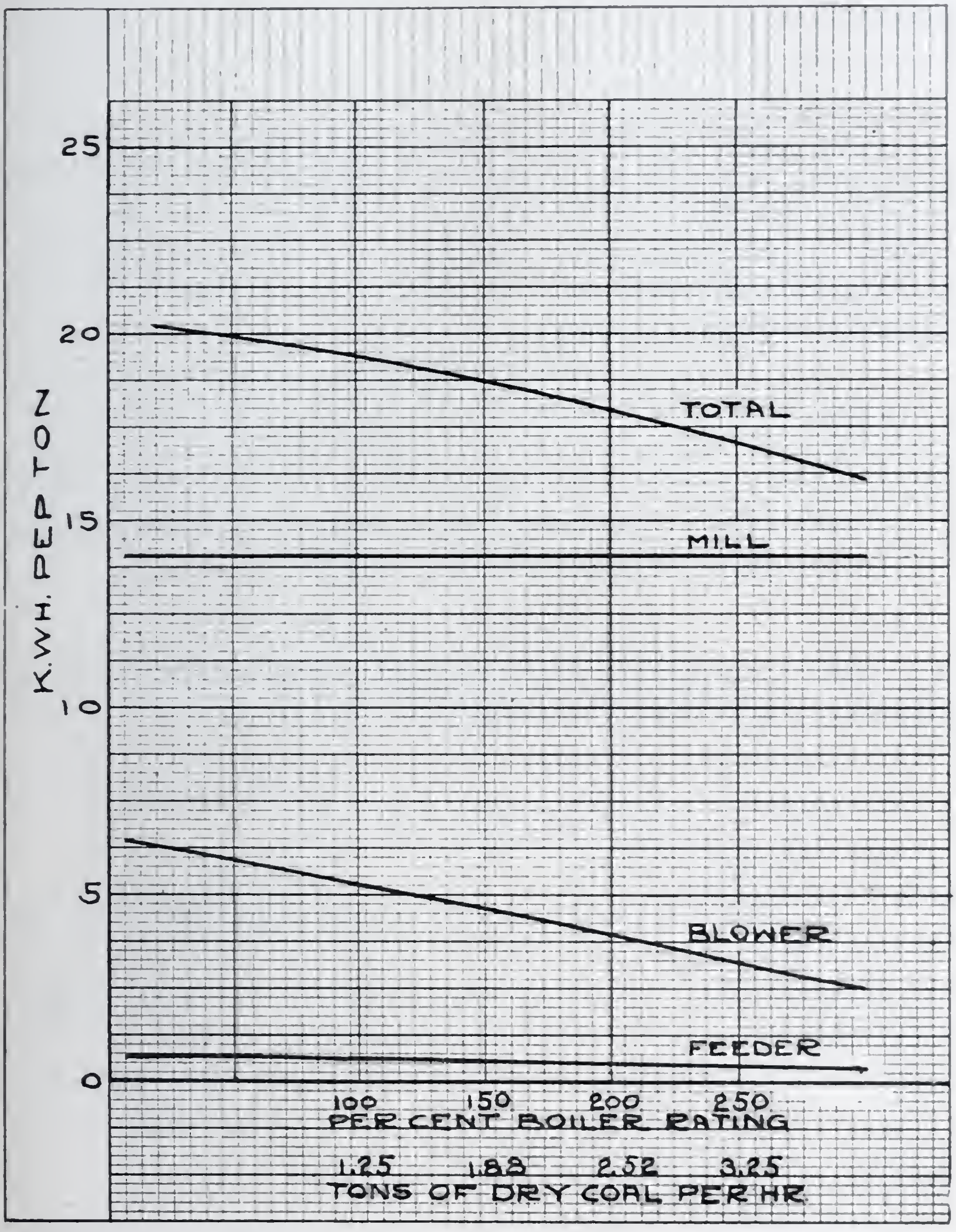

Fig. 13. Power Consumption.

CONCLUSIONS

For large boilers to be operated under central station conditions, powdered fuel appears to be justified for the following reasons:

1. Increased boiler capacity.
2. Increased stack capacity.
3. Increase in the sustained boiler efficiency.
4. Decrease in the amount of fuel required for banking, due to a reduction in the amount of coal in the furnace.
5. Increase in the efficiency of combustion to supply heat loss, and the ease of sealing the furnace and boiler during the banking periods.
6. The number of banking hours is also reduced, because it is not necessary to carry as many boilers under bank, it being possible to start a fire under a comparatively "cold" boiler in a relatively short time. The furnace maintenance under high ratings was reduced due to the elimination of metal from furnace construction.

ANALYSIS OF PROBLEM

Before proceeding with the solution of this problem, let us first clearly define it in the following manner:

Ideal, or exact object sought.

Practical difficulties or problems which must be solved in order to attain or approach the ideal.

Available resources.

Practical solution, or method which appears to be the most logical.

The ultimate object of the engineer was quite well indicated by Tredgold, when he defined civil engineering as "the art of directing the great sources of power in Nature for the use and convenience of man." If he was right (and I am inclined to believe that he realized the function of an engineer more than many who are so called) then the practice of to-day must either be improved, or the definition will become so greatly modified by usage that the dictionary will need extensive revision. It is humiliating to admit that engineers of the present, as a class, now make actual use of only a very small percentage of nature's resources, and throw away or waste the major part.

In our particular combustion problem, the object or the ideal sought is to convert all energy contained in the fuel used, to that form which is best adapted to serve mankind; that is, "Power." The ultimate conversion for most of the energy contained in fuel usually takes the form of power, because power is the greatest servant of man. It relieves him of unnecessary physical labor and drudgery and it is directly and indirectly responsible for practically all of the comforts of modern civilization. Without it we would lack transportation and the many other elements which make possible the social, intellectual, and business life of to-day.

Since most of the power is at present produced by fuel through the medium of the heat cycle, this analysis will be still further limited to the generation of heat.

Combustion is usually considered as the chemical combination of two elements, with a resultant increase in temperature. (Some elements combine without any change in temperature, and others with a decrease in temperature.)

IDEAL

It would be ideal if we could generate all heat contained in fuel and transfer all of it to steam or other vehicle used in the power cycle.

PRACTICAL DIFFICULTIES

Excess Air. During the process, the products of combustion are usually discarded at temperatures higher than that at which they enter the process, thereby carrying away valuable energy. Reducing the amount of excess air reduces the amount of heat carried away. Excess air is usually responsible for a large percentage of the total loss. Its elimination also assists in improving the efficiency of the absorption processes.

Combustible Loss. Foreign matter in fuel, usually known as ash, prevents the combustible material from being burned. Combustible material may also be lost in poorly designed furnaces and through the stack, in solid and gaseous form, due to incomplete combustion.

Furnace Construction. Commercial materials used in furnace construction have not permitted the maximum temperatures

to be obtained without serious damage and costly maintenance.

Ash Removal. The separation of the ash from the combustible, and its removal from the furnace is always a problem.

Radiation Loss. Radiation through the side walls and from the boiler has been hard to eliminate without damage to the furnace.

Absorption. Ash from the combustion process has a tendency to adhere to the heat-absorbing surface of the boiler in the form of clinker and dust, thereby reducing the rate and quantity of heat absorption.

Boiler Reliability. Boiler tubes have a tendency to fail more frequently with higher furnace temperatures.

Practical Operation. Combustion in the past has been almost entirely a "hit or miss" process. Proper control of the quantities has usually been impossible because the operators were not furnished with the facilities required to obtain accurate control. The materials in the apparatus used in the past for burning fuel have usually failed more rapidly when efficient combustion was obtained. The maintenance of the apparatus formerly used in the combustion process not only costs considerable, but required the boiler, and sometimes other apparatus, to be taken out of service while repairs were being made, thereby making an additional overhead expense chargeable to the combustion process.

Exact Object or Ideal Sought. In every-day language, the ideal system is one in which (1) all of the coal is burned; (2) all of the heat generated is transferred to steam; and (3) the apparatus for obtaining this result is so reliable that it can be kept in service continuously without maintenance cost.

AVAILABLE RESOURCES

The resources available to-day are as follows:

Fuel. The available fuel (coal) may contain large percentages of moisture, ash, sulphur, iron, etc.

Materials. Boiler materials which are very good, but limited to a reasonable temperature without failure.

Commercial furnace lining which will withstand a temperature of something over 3000 degrees, but which will fail under operating conditions at temperatures lower than are obtained with

most efficient combustion. Some refractories will resist higher temperatures, but their cost appears prohibitive on account of the large quantities required.

Cost of Operating Labor. Operating labor with an average intelligence properly trained to do specific work.

Highly trained technical men to control combustion can be obtained and justified only in large operations and under good operating conditions.

PRACTICAL SOLUTION

One solution of the combustion process which appears to the writers to be practicable, consists in the firing of coal in powdered form so as to make the process uniform, reliable and controllable. The furnaces are constructed of the best commercial grades of refractory material, and are prevented from failure by limiting the temperatures to which they are subjected. This is done by cooling the furnace walls by means of air and water, so that at no time should the temperature of the refractory exceed the temperatures which they can withstand without injury. The temperature of the refractory depends upon the rate of heat absorption by the refractory from the furnace, and the rate at which it is permitted to give up its heat.

The solution which appears most practical incorporates the various commercial materials available into a system in such a way that none of the materials is subjected to stresses and temperatures beyond which it is absolutely dependable. Metal is eliminated from the interior of the furnace. Refractories are cooled to such a temperature that slag accumulates and forms a protection, and the furnace design made such that no penalty need be paid in the form of lower efficiency in order to prevent damage to the brickwork.

Combustion of coal seems to be more thorough when the coal is fed to the furnace in powdered form than when fed by stokers. Pulverizing alone does not insure complete combustion, but it forms a prerequisite to a quick and thorough mixing of the carbon, hydrogen, sulphur, etc., in the fuel, with the oxygen of the air—the other element which sustains combustion.

In this connection, it might be well to point out that oxygen is just as much a fuel as carbon, hydrogen, and sulphur, and that

because of the fact that the oxygen used is mixed with four parts of nitrogen, an inert gas, it is very important that as little as possible be used in the combustion process, because the nitrogen and the excess oxygen absorb heat which cannot easily be extracted before the product is again given back to the atmosphere.

The trend of modern boiler furnace design for several years has indicated to the writers that the ultimate furnace should be water cooled.

Five or more years ago much attention was being given to the insulation of boiler walls. Insulation can be used to good advantage on that part of the boiler setting which is not exposed to extreme temperatures; but, in order to maintain the furnace lining, it was later found that the insulation should be removed from some parts and the wall thickness decreased in order to save the furnace. Insulation can be used successfully, provided some means are incorporated to absorb heat from the furnace lining fast enough to keep the inside surface below the temperature at which failure occurs.

Air cooling has been used with advantage, but it has the serious disadvantage of requiring air circulation to be continuous, which action interferes with the accurate and absolute control of the air supplied to the furnace. Air-cooled walls require a very high grade of engineering design to meet the various conditions. The ratio of radiant heat-absorbing surface to refractory surface, the quantity of wall-cooling air, air velocity and the location of the cooling zone must all be considered. The strength of the furnace lining, particularly after it has become thin by flame and slag action, may be reduced to the point of failure. An air-cooled furnace should have its walls inclined away from the heated side; and, with tall furnaces, the combustion space is very greatly reduced due to the tapering inward at the bottom with such a design. For instance, in a furnace 30 feet in height, which is being used in some installations to-day, an inclination of only one inch to the foot results in a furnace five feet narrower at the bottom than at the top. With even this much slope, such a furnace would be quickly burned out if the supply of air for cooling is reduced or shut off during a heavy load. Inclined walls may collect slag faster than vertical walls.

With the water-cooled furnace, experience has proved that the temperature of the brick can be maintained below the melting point, and enough slag accumulated actually to protect the brickwork.

The adoption of cooled walls also permits the use of metal hangers such as are used in the suspended-arch construction, so that vertical walls can be utilized.

The writers are very strongly of the opinion that powdered-fuel furnaces in the future will operate on a higher basis with regard to B.t.u. per cubic foot with this type of furnace construction, because it will be possible to make thorough use of the furnace volume. Even the impingement of flame at high velocity on the walls can be permitted without damage.

We are told by scientists that combustion takes place more rapidly with higher temperatures and with higher relative velocities between the combustible elements. Both of these advantages should be obtained.

CALCULATIONS FOR VARIATIONS IN EFFICIENCY WITH CO_2 AND BOILER RATING FOR THREE- AND FOUR-PASS BAFFLES, NO. 31 BOILER AT BRUNOT ISLAND POWER-STATION

These curves are based on the actual efficiency obtained for the boiler under test.

Calculations for the various efficiencies were made as follows:

From the curves showing stack temperature at constant CO_2 versus boiler ratings, values were tabulated for 8, 10, 12, 14, and 16 per cent. of CO_2 at boiler ratings of 100, 150, 200, 250, and 300 per cent.

The actual efficiency for the boiler was then determined for the various ratings at different CO_2 values by applying corrections for the variation in the stack loss, due to heat carried away by the dry gas, with changing conditions.

No correction was made for variations in the stack loss due to the moisture contained in the gases, because this is such a small percentage of the whole that the effect can be neglected for all practical purposes.

The basic efficiency curve for the boiler was determined while baffled with a three-pass baffle. All values for the four-

pass baffle are therefore calculated by applying corrections for the change in stack loss by the method noted above.

The dry stack gas loss is equal to $\frac{W\ (T - t)\ 0.24}{\text{B.t.u. in coal}}$ where W = weight of products of combustion per pound of dry coal; 0.24 = specific heat of gas; T = stack temperature; and t = boiler-room temperature.

Tabulated values are as follows:

FOR THREE-PASS BAFFLES

	Boiler rating per cent.					
CO_2 content of flue-gases		8	10	12	14	16
Pounds of dry gas per pound of coal		20.7	17.6	15.1	13.4	12.0
Stack temperature above boiler temperature, degrees F.	100	134	117	90	82	64
	150	197	176	155	134	113
	200	263	238	213	188	163
	250	333	304	274	245	215
	300	418	381	345	309	272
Stack loss to dry gas per cent. for coal at 13,500 B.t.u. dry	100	4.93	3.64	2.66	1.93	1.36
	150	7.25	5.51	4.16	3.18	2.41
	200	9.68	7.45	5.72	4.46	3.48
	250	12.26	9.50	7.36	5.80	4.59
	300	15.40	11.93	9.26	7.33	5.80
Boiler and furnace efficiency, per cent.	100	79.73	81.02	82.00	82.73	83.3
	150	78.16	79.90	81.32	82.30	83.0
	200	75.70	77.93	79.66	80.88	81.9
	250	71.43	74.19	76.33	77.89	79.1
	300	65.60	69.07	71.34	73.67	75.2

FOR FOUR-PASS BAFFLES

Stack temperature above boiler temperature, degrees F.	100	74	68	61	53	43
	150	123	111	99	88	73
	200	182	164	148	129	111
	250	245	221	198	174	151
	300	—	—	—	—	—
Stack loss to dry gas, per cent. for coal at 13,500 B.t.u.	100	2.72	2.12	1.64	1.26	.92
	150	4.53	3.47	2.66	2.08	1.55
	200	6.70	5.13	3.97	3.06	2.36
	250	9.02	6.90	5.31	4.13	3.21
Boiler and furnace efficiency, per cent.	100	81.94	82.54	83.02	83.40	83.74
	150	80.88	81.94	82.82	83.40	83.86
	200	78.68	80.25	81.41	82.28	83.02
	250	74.67	76.79	78.38	79.56	80.48

DATA ON VARIABLES VERSUS CO_2 FOR THREE- AND FOUR-PASS BAFFLES, NO. 31 BOILER AT BRUNOT ISLAND POWER-STATION

These results are all based on actual test results. The method of determining them was as follows:

1. The CO_2 was held as nearly constant as was possible at a given value and the boiler rating was varied so as to determine the variables (draft loss, stack temperature, and superheat temperature). The variables were determined for four different boiler ratings at each chosen CO_2 value. This gave sufficient data to enable curves to be plotted for constant CO_2 values showing the variables versus the boiler rating.

2. From the above curves, another set was plotted to show the variables versus CO_2 at constant boiler ratings. The points which were taken from the curves plotted for constant CO_2, fell upon smooth curves, thus checking the accuracy of the data.

3. In order to get curves showing the variables plotted versus the boiler rating at constant CO_2 of even percentages namely, 8, 10, 12, 14 and 16) a set of curves was developed from the curves showing constant boiler ratings.

DISCUSSION

Mr. W. C. Buell, Jr.:* The paper is a very interesting exposition of test results, although the writer regrets that the specific data upon which conclusions are based are not available for consideration.

The charts show very clearly the amount of heat in terms of B.t.u. absorbed by the boiler per cubic foot of furnace volume. The subject of furnace volume has long been of considerable interest to the writer, and in order to arrive at the B.t.u. burned per cubic foot the writer has calculated back and finds the following figures which are nearly correct for both the four-pass and three-pass experience.

Rating, per cent.	B.t.u. cubic foot per hour
100	9,400
150	14,000
200	19,000
250	24,500

It is assumed that the furnace in this particular case was premised on continuous operation at 250 per cent.

The writer has had quite a broad experience in the design of boiler furnaces for liquid fuel and has premised the design at maximum rating on 28,800 B.t.u. per cubic foot per hour with an allowable maximum of 36,000 B.t.u. for periods not exceeding two hours, and has never had a case of failure of refractory linings, although air-cooled walls in this practice are unknown. As the efficiencies of the oil-fired boiler and the pulverized-coal-fired boilers at high ratings approximate the same figure, and further as the flame temperatures of both fuels are also approximately the same, and further as oil is nearly always burned with only a fraction of oxygen indicated and with under 10 per cent. excess air, it is reasonable to assume that the oil-flame temperature at the apex of the cone is greater than in coal; and although the fluxing action of the molten ash in the coal fired boiler is absent, it would seem logical to believe that, if anything, the furnace

*President, Buell, Scheib, Mueller, Inc., Pittsburgh.

volume in at least the older installations was greater than it need be.

During the discussion of one of Mr. Kreisinger's papers presented within the last two years, it is the writer's recollection that Mr. Kreisinger stated that the maximum coal to be burned in a cubic foot of furnace volume was 1.5 pounds; or, roughly 20,000 B.t.u.; while better practice seemed to require not more than one pound, or 13,000 B.t.u. Comparing the statement of Mr. Kreisinger and the figures of the paper of Messrs. Hobbs and Heller, and bearing in mind other recent figures on tests, it would appear that the pendulum was swinging in the opposite direction, and an effort was being made to cut down furnace volume, which is largely coming through better burner design and a more thorough consideration of velocities within the furnace.

In the paper we have heard, nothing has been said as to the combustible remaining in the ash. This is a very important point and one frequently not properly considered in the balance. In his tests at Milwaukee, Mr. Kreisinger reports that with the 468-horse-power Edge Moor boiler under test it was found that 25 per cent. of the ash was deposited on the bottom of the furnace; 20 per cent. between the second and third pass; 15 to 20 per cent. in the economizer chamber; 10 per cent. on the floor of the main flue; while the balance, 15 to 30 per cent., passed out of the stack. Many thoughtful investigators are finding upon careful analysis that quite a large proportion of the substance ordinarily reported ash, contains a large proportion of free carbon, and possibly the authors of this paper can add some valuable information on this point.

Another point touched upon, which is of great value, is the subject of stack size. In oil practice the writer has always divided Kent's capacity figures by two, and in spite of this has always had ample capacity.

One other factor in the operation of the plant, that has been touched upon, is the power consumption figures for the blower air. The curve given indicates that the blower must reach its maximum efficiency at a point above 300 per cent. rating. If this line, which is shown as a straight line function of "tons of coal," were extended to approximately 500 per cent. rating, the

power for air would be zero; whereas, as a matter of fact, after reaching its most efficient volume delivery point the power factor must increase rapidly, for the volume of air required through the burners from the blower must increase with the loss of stack draft, which is rapidly falling at the higher capacity.

MR. HENRY KREISINGER:* I wish to congratulate Mr. Hobbs and Mr. Heller on the neat presentation of the data contained in the paper. The paper forms a valuable addition to the information on the burning of powdered coal. It is valuable because it contains experimental results—known facts actually obtained in the operation of a boiler fired with powdered coal. It is not a mere opinion that this or that may happen if something else were so. We must make this distinction between this paper and other papers where figures and opinions are presented without any experimental evidence or data obtained in actual operation. I know that the results given in this paper are reliable because I have given considerable attention to these tests and I watched them while they were being conducted.

What I get out of this paper is principally this: Powdered coal gives higher efficiency—higher capacity—than any other method of burning coal or burning of any other fuel, oil and gas included; and I think the experimental data amply prove it. The paper also shows that the higher efficiency can be maintained under variable load conditions, which can not be done so easily with other methods of firing. It also shows that the banking losses are small because, if the boiler is not needed, the fires can be taken out completely and the furnace closed and no coal needs to be burned during the period of banking. When the boiler is needed the coal can be turned on, the fires lighted and in a few minutes the boiler can be on the line. These are the main features I get out of this paper.

Higher efficiency and capacity are possible because the coal can be burned almost completely with very low excess of air. That is the key to the success of powdered coal. With other methods of firing, the incomplete combustion losses may amount to from 5 to 10 per cent. These incomplete combustion losses in-

*Research Engineer, Combustion Engineering Corporation, New York City.

clude unburned combustible gases and cinders escaping into the stack with the gases, as well as the unburned carbon in the refuse. With powdered coal the incomplete combustion losses can be held down to two or even one per cent. The excess air can be kept low continuously, as one of the charts accompanying the paper shows. Instead of having the excess air running all the way from 25 to 105 per cent. it can be maintained easily between 10 and 25 per cent. Now, small excess air means small losses in dry chimney gases; small chimney losses mean high efficiency; but with complete combustion and low excess air we necessarily get higher furnace temperatures.

Higher temperatures always bring two problems to solve and those problems are riddance of ash, and endurance of furnace lining. With high furnace temperatures the ash usually fuses and runs down to the bottom and can not be removed except by cooling the furnace and sending men into the furnace with pick and hammer to mine out the slag. As to endurance of the furnace lining, the fused ash runs down the wall and washes away the furnace lining and takes it along the bottom of the ash-pit. Only a few days ago Mr. Orrok told me about his first experience with powdered coal. He said when the furnace was started the coal burned beautifully but before they completed the first test the furnace was burned out. They did not even complete the test. Although they may have secured complete combustion and high efficiency the furnace did not last; therefore the endurance of the furnace lining is a very important factor in burning coal, as well as the riddance of ash which makes it possible to keep the boiler continuously in operation.

Now if we wish to burn powdered coal successfully we must solve those two problems. In the installation on which the experiments described in the paper were conducted the bottom of the furnace was screened by a row of tubes through which water circulated. In fact those tubes were part of the boiler. The ash as it was falling through those rows of tubes solidified before it reached the bottom, and was deposited largely in the form of dust or powder with small pieces of clinker that could be easily removed while the boiler was in operation. In fact, steam jets were installed in the front of the furnace to blow the refuse deposited at the bottom to the rear of the furnace from where it could be

removed with a short-handled hoe. That is a solution of the problem of the riddance of ash.

The other problem—the endurance of the furnace—is largely solved by making the walls hollow and passing through the hollow walls a large part of the air needed in combustion. In that particular case about 60 per cent. of the air needed for combustion was passed through these hollow walls before it entered the furnace. In passing through these hollow walls the air abstracted heat from the furnace lining and carried it back into the furnace into the combustion space. Thus the air took the heat out of the furnace lining where it was not wanted, thereby causing the furnace lining to cool, and carried it into the combustion space where it was wanted. This process kept the furnace lining at sufficiently low temperature so that the lining was not washed away to any considerable extent by the molten refuse that might have been deposited on the walls. Of course, the air that is circulated through the walls cannot very well enter with the coal. That is not necessary. I know there are advocates who claim and argue that all the air should be supplied with the coal because, they say, it quickens combustion, but experimental results show that this is not the case. Ignition of powdered coal is the quickest when only about three to four pounds of air are supplied with the coal. I will put this in another way. The inflammability of coal-dust mixture is the quickest when only 30 to 40 per cent. of the air needed for combustion is supplied with the coal. If we go beyond that ignition slows down. If all of the air needed for combustion is supplied with the coal, the ignition is much slower than if only 30 to 40 per cent. of the air is supplied with the coal. In fact, the fire may blow out completely Those who attempted to burn anthracite with all the necessary air supplied with the coal had that experience—the flame puffed or blew out.

This feature can be illustrated by Fig. 14. In this chart the scale at the bottom gives the ratio of air to coal in a mixture. The scale at the left gives the relative velocity of flame propagation, approximately, in meters per second. The curves show the velocity of flame propagation for different coals with varying ratios of air and coal in the mixture. It is shown that the higher the percentage of ash the lower the velocity of flame propagation; also, the lower the percentage of volatile matter the lower the

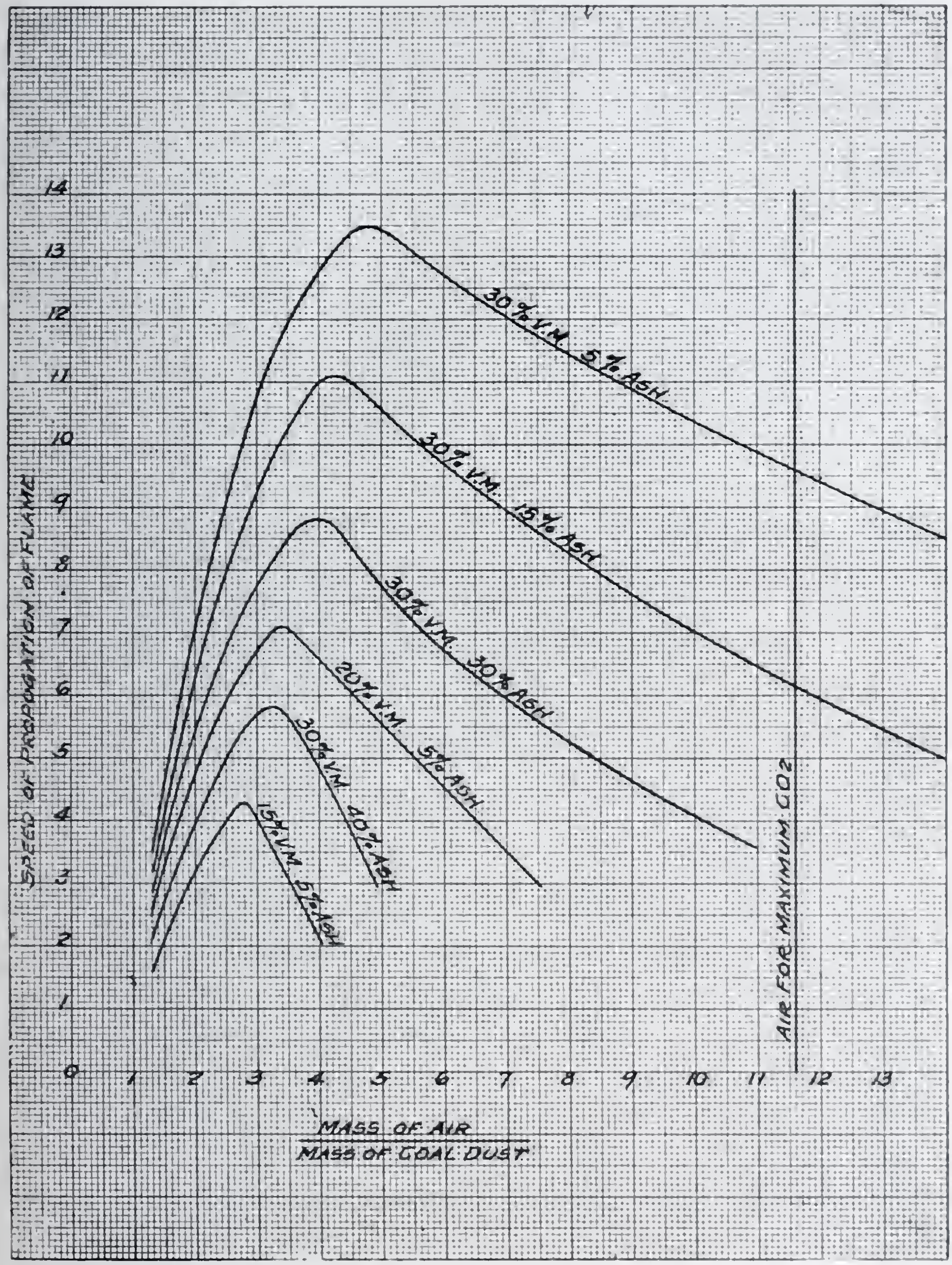

Fig. 14. Velocity of Flame Propagation as Influenced by Ratio of Air to Coal.

velocity of flame propagation. With most of the coal the maximum velocity of flame propagation is with a mixture of 2½ to 5 pounds of air to a pound of coal.

Taking the second curve from the top, which represents nearly the kind of coal used for steaming purposes in this country with a mixture of four pounds of air to a pound of coal, we can introduce the mixture into the furnace with a velocity of 50 feet per second and the flame will be steady and kept quite close to the burner; whereas, if we put seven pounds of air to a pound of coal the flame will blow away. It will not necessarily blow out, because farther away from the burner the velocity will slow down and the flame will find a place where the velocity of the mixture is equal to the velocity of flame propagation. If there is a slight variation in the mixture, the flame will travel on the stream of the mixture and we will have puffing or pulsation. With anthracite there should be less air entering with the coal. It stands to reason that air cannot enter into combustion until it has been heated to about 1800 degrees F., and when we use 10 pounds of air instead of three with the coal, we have to heat 10 pounds of air instead of three, and it will take longer to raise this large quantity of air to the high point of ignition temperature. I am just bringing this feature in to show that we are not losing anything if we circulate 60 per cent. of the air through the hollow walls. We have better combustion and are saving our furnace lining besides.

I may add that these velocities shown in Fig. 14 were determined by experiments in France in connection with coal-dust explosions in mines and some of them have also been worked out by the United States Bureau of Mines.

In connection with the air-cooled wall, Mr. Hobbs said that the air-cooled wall must be made inclined away from the furnace because it would fall into the furnace. He forgets that he puts a wall upside down in the furnace in the form of a suspended arch and it stays there Why can we not build a vertical wall and tie it as we do the arch? We do not need to depend on the strength of the brick. Fire-brick should not be used for strength, as that is not its purpose. The builder of the sky-scraper does not depend on the brick for his strength; the steel supplies the strength. Build a steel cage to support the furnace and fill the walls with refractory. The refractory has no tensile strength and

no compression strength to speak of and we should not expect it to stand stresses. The main object of the refractory is to keep the heat in the furnace and resist the abrasion of the molten ash.

The authors pointed out the future direction in which the development of furnace design will take place. They say the future furnaces will be completely water cooled That is probably the way it will go; but in making these water-cooled furnaces we must be careful how we put the water-cooled surface in the furnace. If we put it in the wall or very close to the wall these tubes are going to slag over in time, and this will gradually build out until it will reach such thickness that the slag will remain molten and it will run, and if we reach that condition we will have trouble. To my mind, the tube should be put in in such a way that this slag will freeze before it hits the wall and before it has a chance to deposit.

These remarks are merely supplementing and not controverting what the authors said about water-cooled furnaces. The water-cooled furnace is a step in the right direction. I am merely pointing out how the screens must be put in the furnace.

MR. FRED J. CROLIUS:* The thought which Mr. Hobbs's definition of an engineer arouses is that "an engineer is one who anticipates constructively." The thought is emphasized at the moment by the rapidly shifting list of engineers who have jumped the fence of combustion, and now admit that pulverized coal may have a future. Such careful investigation by such thoughtful men as Mr. Hobbs and Mr. Heller does more to convince the skeptics than tons of misstated publicity.

There was a reason why John Muhlfeld and Carachristi undertook their early work; why John Anderson took powdered coal into Milwaukee; why Ford pioneered the combination of blast-furnace gas and powdered fuel—to be followed by Frank Cutler at Tennessee; Bill Stoop at La Belle; Ritts at Spang, Chalfant; and Stahl at Narragansett. There were reasons, definite reasons, why these and others whose work has been just as fundamental, though less heralded, went ahead; but the principal

*Editor, Blast Furnace and Steel Plant, Pittsburgh.

reason in each instance was the presence, in the background, of a true engineer—a man who anticipated.

The experimental stage is largely past; the art now possesses a foundation built on statistical facts such as those just presented.

Duquesne Light has "pioneered," but in a most conservative way. The results shown so interestingly were obtained from a single unit of unique characteristics, and the chief criticism of the paper which suggests itself, is that many of the unusual phases of the development, which must have arisen and been solved were not cited or mentioned.

The comparison of baffle arrangements in relation to capacity, overall boiler efficiency, and amount of superheat is good.

The relations between CO_2 and boiler rating, stack temperature, superheat and draft loss, are interesting in that they present conditions known and discussed, but never made definite.

The curves of power consumption could have been made doubly valuable by comparison with curves of power requirements of a stoker-fired unit of relative capacity, unless, as the conclusion suggests, the findings regarding advantages of pulverized fuel were so pronounced as to preclude the necessity of stoker comparisons. If this were the case, the authors might well have given (1) greater details of the length of time of actual service; (2) the number and length of periods of stoppage for any cause attributable to the pulverized method; (3) the actual cost of furnace repairs over a definite period, and the expectancy of repairs over a projected period; (4) in the curves of power consumption, the degree of fineness of pulverization; (5) the degree of fineness which their experiments suggested as pratcical; (6) the power consumption with various degrees of fineness.

The analysis of power consumpion shows a charge for feeders. Of what value were feeders, to warrant a charge?

The analysis shows a declining charge for the blower (with increased rating). What volumes of air were handled by the blower, and how much would blower power be increased if all the air for combustion were handled by the blower?

Why does the mill power remain a constant over a range of 1.25 to 3.25 tons per hour using a six-ton roller-type mill?

After all, is not the question one of economy, not efficiency. what is the cost of efficiency? And if it is, what is the most

economical method of preparing fuel, and firing it, conforming at all times to the engineer's ideal?

Is it economical to create sufficient vacuum to draw a continuous tonnage of ground coal out of a pulverizer, lift it to an unusual height into a cyclone separator, there dissipate the developed pressure to atmospheric, and then again develop an identical pressure to transport that fuel (both coal and air) into a boiler furnace?

Is it economical to grind 85 per cent. 200-mesh, when 85 per cent. 100-mesh coal will result in identical efficiencies.

Is it economical to pass the total tonnage of ground coal over the fan blading, when the same results may be obained without that inevitable wear and tear on fans?

Is it economical to dry the coal before pulverizing, when the amount of moisture in the coal hardly compares with the amount of moisture in the air for combustion; especially when both moisture values are factors in reducing the furnace temperatures. which all acknowledge is most desirable under the present limitation of refractories?

Excessively large furnaces have been built; air ports, water screens, and all sorts of devices have been tried; certain accepted standards of volume to fuel have been built up; but no one is yet certain enough to go on record that a satisfactory furnace exists.

Water cooling in some form or other seems to be admitted by all; but what form of water cooling is best?

Are we quite certain that the large furnace is absolutely essential? Isn't it rather a question of the time element of combustion and if combustion could be hastened to the *point of the burner,* would it be economical to build large furnaces? The open-hearth furnace is a point in comparison. Less than 10 years ago. no open-hearth man would countenance a "forced combustion." He was educated to long flame and considered that essential to tonnage. To-day the Egler, the McCune, and the Loftus furnaces bid fair to revolutionize that idea.

Much remains to be done, but when the stage is reached when no power project involving solid fuel, when no large extension is planned, without most serious consideration of the desirability of pulverized fuel, it may be accepted for granted that the idea is

sold. What is necessary now is a frank analysis and discussion of costs—a complete summation of the "cost of efficiency."

MR. C. F. HERINGTON:* In the paper as presented, the writer can find no criticism whatever. The facts as presented are in keeping with what is being accomplished in pulverized coal firing and no one, I am confident, would want to predict what further economies will be effected by this fuel in the future, nor would anyone say that we have reached the limit and can go no further in this matter of burning coal.

It was in the year 1913 that the writer witnessed his first burning of pulverized coal in a boiler furnace. An ordinary return tubular boiler with an extension to the fire-box, having the grates removed, was used. The coal was ground to a fineness of about 60 mesh, fed into the top of the fire-box through an ordinary pipe nipple, while the secondary air was admitted through the sides of the furnace under a pressure of one ounce. In exactly 20 minutes the fire-box door was being melted by the intense heat. The combustion space was too small. According to the size of the combustion chambers now being used this combustion chamber was less than 20 per cent. of the size it should have been. With the above results, the trials were shortly discontinued.

Consider for a moment the small size of the combustion chambers used for stokers right up to the present day—all of them too small. It is only recently that the stoker people in considering the great success of large combustion chambers, realized their mistake of long standing and are publicly acknowledging that the art of burning pulverized coal under boilers has placed them on the defensive, and some have gone so far as to form pulverized coal departments.

The writer has for years suggested that there were at least a dozen good reasons why pulverized coal is a success under boilers.

1. Pulverized coal can successfully use low grades of fuel, whereas no one stoker will or can burn all grades of coal.

For instance, at the Lykens plant of the M. A. Hanna Company, refuse coal from culm banks is being successfully pulverized

*Contracting Engineer, Heyl & Patterson, Inc., Pittsburgh.

and burned under boilers. Perhaps a brief report upon the writer's visit there will be of interest to some of you.

The powdered coal plant, which has now been in successful operation for over a year, has Edge Moor water-tube boilers—six of 500 horse-power capacity each, operating at 190 pounds pressure and 75 degrees superheat; and six of 600 horse-power, operating at 150 pounds pressure without superheat. Foster superheaters are used on the 500-horse-power boilers. The raw coal is comparable with our river coal in size and runs from 18 to 24 per cent. in ash, about 7.5 per cent. volatile, and as high as 10 per cent. moisture.

The coal is pumped from the culm banks to storage on the hillside above the power-plant by means of plunger pumps which elevate the coal about 400 feet in a single lift. The coal to be pumped is drawn from a pool of water and the mixture as pumped contains from 20 to 25 per cent. solids. The pumps deliver the coal to receiving boxes, from which it is picked up by drag elevators and deposited on the storage pile. Drag lines bring the coal from the storage pile to the coal drying and pulverizing plant. There are two Ruggles-Coles driers in which the coal is dried to below one per cent. moisture. These driers are fired with No. 2 buckwheat and consume 60 pounds of coal per gross ton of wet coal. From the driers, the coal is carried by screw conveyors to the dry coal bin above the pulverizers. There are four Fuller-Lehigh belt-driven mills which pulverize 2.5 to 2.6 gross tons of coal per mill per hour. Two additional Fuller-Lehigh pulverizing mills are being installed but these are gear driven. This type of drive was decided on as a result of difficulties with belting. The drying and pulverizing plant is operated two eight-hour shifts per 24 hours, leaving it idle on the day shift when the power load is the heaviest. Screw conveyors bring the powdered coal to the boiler house where it is elevated and again conveyed by screws to the bins over the individual boilers. All conveying machinery is built in duplicate and arrangements are being made so that either conveyor in any set of two can serve as a spare for the other. The two screws which convey the coal from the elevators and distribute it to the boiler bins are 16 inches in diameter and 200 feet long. Each has a capacity of 30 tons an hour and each is driven by a 50-horse-power motor. The boilers are arranged in

batteries on either side of a central coal bin with compartments of 36 tons capacity, one compartment to a boiler. Screw conveyors feed the coal from the bin compartments to the burners through Y-shaped pipes, the burners receiving coal through one branch and air through the other branch of the Y. The pressure of the air at the burners varies from two to four inch water column. About 50 per cent. of the air needed for combustion is furnished in the manner described and the balance is furnished by infiltration, chiefly at the breeching. The boilers are four-pass and have a combustion chamber 21 feet deep from the tip of the burners, which shoot the flame from the top down in a vertical direction. The boilers are 16 feet 6 inches wide over all the brickwork. Measured longitudinally with the boiler, the combustion chamber is four feet, six inches at the bottom and 12 feet near the top, with an arched partition wall between the burner and the first pass of the boiler. Measuring in the same direction, the first pass is about seven feet clear in the brickwork. The second and third passes have a five-foot space in the brickwork, which space narrows down to a dust collector. The fourth pass has a two-foot connection to a dust chamber ahead of the stack. The burners are made fan shaped and spread the flame in a plane at right angles to the boiler. The tips of the burners are movable so the fan of flame can be brought to bear against the front or back wall of the combustion chamber. This arrangement permits deposits on these walls to be burned off in regular operation and dropped to the bottom of the combustion chamber. The two sides of these chambers are sloped about 45 degrees and, by running water on these sides, ashes and dust are carried directly into a sewer and flushed out of the boiler house. A kerosene pressure tank with piping to burners on the individual boilers provides convenient means to light the boilers quickly and cheaply. A considerable wood fire would otherwise be necessary to bring the combustion chamber to a sufficiently high temperature to ignite the powdered coal. The boilers come off for cleaning every six weeks to two months. The monthly average boiler efficiency is 81 per cent. The operating force in the boiler house consists of two water tenders and two firemen per shift. There are five men employed per shift on the operating force of the pulverizing

plant. There is also one foreman in charge of the boiler house and one for the pulverizing plant.

The total power consumed to prepare a gross ton of dust is 29.81 kilowatt-hours, of which 22.8 kilowatt-hours are consumed in grinding only, the balance being used for conveying and drying. The steam cost for the months of March 1922, including pumping and preparing, running at 120 per cent. boiler rating, figuring the raw fuel at 50 cents per gross ton but not including any interest on investment nor depreciation, figures 12.03 cents per thousand pounds of steam.

The following averages are taken from a number of analyses of powdered coal:

Through 200 mesh	80	per cent.
Moisture	46	per cent.
Volatile	7.5	per cent.
Fixed carbon	69.6	per cent.
Ash	20.2	per cent
B.t.u.		11,700

The analyses varied slightly only as to size of coal, volatile matter ran as high as 8.123, and the B.t.u. values varied from 11,300 to 12,200.

2. Pulverized coal is flexible in its application and control; that is, it has the ability to take care of peak-loads at a moment's notice.

This reason is without doubt admitted by all who have had experience with pulverized coal and even those who have seen its application will admit of the possibilities.

3. No stand-by losses are necessary, as the closing of the valves immediately stops the burning of the fuel, and pressure can be maintained on the boilers from 6 to 10 hours with a very small loss, and in a very brief time brought back again to normal operating rating.

In support of the above reason the following incident is cited. At the Lakeside station of the Milwaukee Electric Railway and Light Company, one of the boilers was being operated at 160 per cent. rating with steam pressure at 270 pounds, the coal feed was shut off and the dampers closed, the pressure remained constant for three hours, and at the end of 12 hours the pressure had dropped to 160 pounds, but in five minutes after

turning on the coal feed the pressure was again brought up to 270 pounds.

4. Complete combustion is secured without the loss of unburned coal through the grates, as no grates are required with pulverized coal.

At one of the stoker plants operated within 100 miles of here the author saw an analysis of the ash from the boilers which contained 25 per cent. unconsumed carbon.

5. Less excess air is required with pulverized coal as there are no grates to force air through and the coal is fed into the combustion chamber of the boiler enveloped with air.

The above reason needs no further explanation.

6. Pulverized coal reduces the repairs on the brickwork of the furnaces, providing the correct design is made.

Here is a reason that perhaps we do not all agree upon and which therefore requires an explanation. The boiler mentioned this evening was of 822 horse-power operating at 300 per cent., or developing about 2500 horse-power. I understand that the input of this boiler at the above rating was 36,000 B.t.u. per cubic foot of combustion and also that the volume of the combustion chamber was 4300 cubic feet. If the coal contained 14,000 B.t.u. per pound, there were burned 1.85 pounds of coal per cubic foot of volume and thus 7955 pounds of coal were burned per hour under this boiler, developing 2500 horse-power; or over 3.1 pounds of coal were burned per horse-power developed.

A combustion chamber of the above size, including an air space, will contain 100,000 bricks—60,000 red and 40,000 fire-brick—and with a cost of $23 plus $35 for labor per thousand on the red brick, and $52 plus $47 for labor on the firebrick, this combustion chamber will cost approximately $7500, or about $3 per boiler horse-power developed as the first cost of a combustion chamber.

As the present combustion chamber has been in operation since September 1922, up to the first of June makes nine months and if we assume that the average horse-power developed was 2000, we have 12,960,000 horse-power hours developed in 270 days, and if it were necessary (which it is not) to rebuild a complete new combustion chamber at the expiration of nine months,

the maintenance cost has been only 0.0057 cents, a little less than 1/17 of a cent per horse-power hour.

7. Less labor is required in the boiler room than is necessary with stokers.

It is no arduous task for one man to operate five 800-horse-power boilers when fired with pulverized coal.

8. The dirty and costly work of removing large quantities of ashes is unnecessary with pulverized coal.

The Ford plant at River Rouge designed an ash hopper so as to remove ashes by freight cars, but they are at present using a wheelbarrow instead. Men have been sent looking for ashes within a radius of 12 miles from this boiler plant and have been unsuccessful in locating any.

When the new plant for the city of Detroit was proposed, a bill was introduced in the city council by some friend (?) of the pulverized-coal industry prohibiting the city from constructing a pulverized-coal boiler plant within the city limits. The council, after receiving statements from the city officials of Milwaukee that they had found no objection to the burning of pulverized coal within a block of the city hall, killed the bill.

9. Higher ratings can be made more quickly and maintained more uniformly with pulverized coal than is possible with stokers.

My understanding of this reason is that with stokers a constant rating of 200 per cent. can be obtained for periods of three months. Then the stoker fails and for short periods of 72 hours or possibly a week a rating of 300 per cent. can be obtained; but with pulverized coal a continuous raitng of 250 to 300 per cent. can be maintained with no break occasioned by any of the pulverized-coal apparatus, but the boiler fails to stand by. This of course is known to the boiler manufacturer and is being corrected.

10. As the coal is dried before being pulverized, a dry combustible is supplied thus removing the necessity of evaporating the moisture in the boiler furnace, and the consequent loss of efficiency.

At the present time this question is being very widely discussed and although volumes may be written regarding the relative advantages and disadvantages of drying coal, the fact remains that the engineers at Milwaukee have tried operating without driers but are now using them. The new Providence electric light

plant is using them, and the new Detroit Edison is contemplating their use as is also the new plant for the city of Detroit.

11. The maintenance of a plant is considerably less with pulverized coal than with stoker equipment.

12. With a boiler designed for pulverized coal, other fuels can be substituted quickly, or can be used in connection with the pulverized coal.

MR. EDWARD RAHM, JR.:* We have listened to a very interesting paper, and the authors are certainly to be commended for the original information brought out. The discussion of Mr. Kreisinger deserves considerable comment.

The performance curves submitted by the authors, calling especial attention to the fact that the higher the furnace temperature the lower the superheat and stack temperature, suggest the thought that the superheater of the future in connection with pulverized-coal firing for steam generation will be of the radiant type. In many cases this may be a substitute for the water-jacket endorsed by the authors and favorably commented on by Mr. Kreisinger. These superheaters are now constructed by all the leading companies and there are several advantages in their use. Draft losses through the boiler are cut down by taking the superheater out from the nest of tubes where it is customarily located and placing it in the combustion chamber. This gives more heat-absorbing surface in the combustion chamber proper and thus permits less excess air to be used with consequent higher CO_2. The refractories are protected and a large section of the furnace wall is replaced by the superheater, so that there are less refractory surfaces to be protected against erosion and eutectic action of the brickwork. The superheat curve with the radiant type is flatter and it is in accordance with correct principles of design to obtain the superheat from the highest temperature gases. To a great extent it is independent of the CO_2 content of the furnace gases.

I do not like to take exception to any remarks by Mr. Kreisinger as I have a great respect for his past experience and his ability. Nevertheless there is always room for an honest difference of opinion, and I think he should have run that flame propagation curve out a little further. It illustrates what happens with

*Manager, Industrial Equipment Co., Pittsburgh.

a high-pressure burner with coal entering at high velocities, and I do not dispute for one moment the results shown by this curve. However, an extension of this same curve shows that with low velocities at the burner it is possible to get good flame propagation while admitting all or nearly all of the air necessary for combustion. The writer has installed a number of pulverizers which are operating very successfully under this condition.

Personally I prefer to admit the air and coal into the furnace at low velocity and it is self evident that this method will require less power expenditure. With the coal entering at high velocity as in this installation discussed this evening, greater furnace depths are desirable. It is almost absolutely necessary to preheat the air by a hollow wall setting or other means so as to get quick ignition to the rapidly moving coal and air, and it is almost absolutely necessary to admit air through the front wall so as to turn the flame away from the wall and cause it to follow a U-shaped course. This largely explains why hollow wall settings are advocated with this system of pulverized-fuel firing.

I agree with the authors that the hollow wall has certain drawbacks which make it a doubtful question as to whether the hollow wall setting is worth the trouble. Every installation that I have had anything to do with has a solid wall setting and I might say that they compare very favorably in maintenance with the hollow wall settings. Furthermore you do not have to charge up a half-inch draft loss to pull or push air around the setting. Also, as the authors have pointed out, you have a greater opportunity to synchronize your coal and air properly at various ratings

I believe that in this part of the country the water screen to prevent the fusing of the ash is unnecsesary. In this district there are several successful installations of various systems operating without water screens and with dry ash easily removed. The fusing point of ash with coals in this district varies from about 2100 to 2400 degrees F., and this does not present such a difficult ash-handling problem. As long as you have sufficient heat-absorbing surface in the combustion chamber, such as radiant-element superheaters or large banks of tubes directly exposed to the radiant heat of the furnace, the question of slagging ash is largely solved.

Looking into the future of this very interesting subject, I believe that we shall soon see boilers especially designed for pulverized coal with full provision for heat absorption by radiation, with convection and conduction as almost negligible factors. Gas passages will be differently arranged with cross-sectional areas proportional to the volumes of the gases, and the speed of gas travel will be much lower than with stoker operation.

Mr. J. B. Crane:* Messrs. Hobbs and Heller have made a valuable contribution to the knowledge of results to be obtained by firing boilers with pulverized coal. However, they suggest certain matters that may be improved upon, and show that the final word cannot yet be written. We still lack definite information as to operating efficiencies over long periods, and costs of pulverizing equipment; but, if the use of all the pulverizing fuel plants were discontinued to-day, we would still have to credit this method of firing boilers with the biggest advance in boiler-room design that has ever been made.

When underfeed stokers were first installed, they were adapted to old boilers and dimensions set by hand grates. The stokers burned a little more coal per square foot of grate area and consequently the boiler operated at a little higher rating; subsequently two stokers were put under one boiler with a common ash discharge, but it was not until pulverized coal under boilers was successfully used that the stoker people really got busy and developed the superpower stoker.

To-day enough coal can be burned per foot of furnace width to develop 250 horse-power of boiler capacity and, assuming 200 per cent. of boiler rating, this means 12,500 square feet of heating surface per foot of furnace width, which is two to three times that formerly used. This means a saving in first cost and a better operating efficiency, as there is less radiation loss and a lower exit temperature of the gases.

Mr. Joseph Breslove:† As engineers, we like to pride ourselves that we are above such matters as style, but there are still styles in engineering as in other things. Powdered coal came in actively a few years ago and is rapidly approaching the period when it may be considered in style; in fact, it has reached

*Vice-President, George T. Ladd Co., Pittsburgh.
†Consulting Engineer, Pittsburgh.

a point where it is gaining considerable momentum and becoming a formidable rival of the stoker.

This excellent paper dealt particularly with powdered coal as applied to large boilers. This is also true of the other speakers but I think we are leaving out a very important element if we do not include the small boiler. In this connection the point I wish to make in favor of powdered coal is not so much its efficiency or fuel economy but the greater ease of operation. It will not be so difficult to get operators for powdered-coal furnaces as it is to obtain good operators on stoker-fired furnaces.

The modern stoker is an intricate mechanism requiring a high-class man for its best operation. This man must be something of a combination of engineer, fireman, machinist, and combustion man. It requires close application to obtain the best results and to maintain the mechanism in good operating condition. The firing of the fuel and the mechanical maintenance are interconnected beyond dissolution, owing to the fact that the coal is fired on the mechanism itself. In the case of powdered coal the actual combustion or firing of the furnace may be separated from the grinding and feeding mechanisms. The machinery for this purpose may be taken care of by the ordinary mechanic who need have no special knowledge of combustion, it being his part to maintain the equipment in a mechanical condition so that it will grind and deliver the coal at a certain point. At this point the coal is burned in a furnace without mechanical contact and as such it is purely a combustion problem. Having adjusted the fuel and air for the conditions, the operator can more easily take care of this part of the work than in stoker firing. This is particularly important in the smaller plants where the conditions will not justify a high-class fireman, such as may be available for the larger plants, the latter being in a better position to secure high-class operators. It should not be so difficult to train an operator for firing powdered coal as for operating stokers.

Along the lines of smaller operations there is a 500-horse-power (normal rating) boiler plant at Herrs Island which has been in operation for one and a half years carrying an average load of 800 to 1000 horse-power. This plant is not tuned up for the maximum fuel economy but the operators are obtaining average overall efficiencies greatly in excess of what could be accom-

plished by the same type of men with stokers. It is, of course, essential in the small plant that the powdered coal installation be of the simplest type resulting in a minimum of machinery and the smallest number of adjustments. If the furnace is properly designed, the operator should have no difficulty in following instructions and obtaining fair average economies with low maintenance costs.

Reverting again to the question of styles, it is important at this phase of the development that careful consideration be given to the type of plant before jumping to the conclusion that powdered coal is the cure for all diseases. There are certain parts of the country where very friable coals are mined. These adapt themselves beautifully to pulverization while there are other coals which are much harder to grind and in which the grinding costs may reach a point such as to offset any real gain in economy. To burn pulverized coal successfully at high ratings requires comparatively large furnaces. There are plants, however, where high ratings are required part of the time and the remainder of the time the load is practically negligible. This involves difficulties not inherent with the stoker where a fire may be maintained on the grates. The large furnace volume results in rapid cooling and it is difficult to maintain combustion in a pulverized-coal furnace designed for high ratings when the load drops down below certain values. This condition is more prevalent in the small plant with a widely fluctuating load than in a large plant where the number of boilers in operation is proportional to the station load. The next development will probably be in the line of furnace design which will be equally suitable for low ratings as well as high ratings. With this problem solved, powdered coal should come very rapidly into use with smaller boilers. Finally, the question of fuel economy, while extremely important, should not be the only factor under consideration. With the labor problem becoming more difficult, the question of comparative ease of operation may, in some cases, be even more important.

Mr. A. E. Blake:* There is one important fact about powdered coal which has not thus far been brought out. With-

*Pittsburgh Representative, U. G. I. Contracting Co.

out reviewing the advantages which are gained in pulverizing the solid fuel, I would like to point out that practically all of them are due to the fact that, in use, powdered coal is very similar in its combustion properties to gaseous fuel, and I think it will be agreed by everyone here that success with powdered coal is chiefly due to this. The disadvantages, such as the ash problem, smoke, dust, and the mechanical difficulties incident to grinding, distributing and supplying air, are due to the fact that the coal is not gas.

Someone has stated that the smaller the boiler setting the more finely the coal should be ground. This is in line with the thought just expressed, because the more finely the coal is ground, the greater are the chances for complete combustion in a small setting. I do not think that all of the makers of powdered coal equipment have kept this importance of fine grinding in mind when the coal is to be used in numerous small furnaces, where the size of flame should be small enough at least to be contained within the furnace itself if any reasonable efficiency is to be secured.

I think that the powdered coal process is admirably adapted to steam raising, but in leaving that field of application, those legitimately remaining to powdered coal are exceedingly few, and limited to the larger furnace installations operating on the higher ranges of temperature, and without particular demands as to cleanliness, uniformity of temperature, etc. In this district, at least, it is a very simple matter to show that ordinary industrial furnaces are far more cheaply heated by means of gas, either natural or manufactured, and this is bound to remain true.

Mr. J. C. Hobbs: After Dr. Kreisinger has made a special trip from New York to Pittsburgh, I don't believe he should be unduly criticized. We appreciate the information he has given us, and all realize that he does his work on the basis of facts.

You will remember his exact words concerning bricks and boquets when he said he was going to build that vertical wall and "hold it up just like an arch." Any operating man knows what that means.

With reference to the matter of air cooling, may I presume to criticize his suggestion that the cold surface be placed out in

the furnace. One of the other speakers mentioned the difficulty of handling furnaces at low rating.

As in stoker practice, too much radiant-heat-absorbing surface will undoubtedly affect the furnace efficiency and even its satisfactory operation. It is the writer's opinion that the walls must be water cooled, but that the interior surface of the furnace must be composed of refractories consisting either of fire-brick or accumulated slag, so that the furnace temperature can be maintained. This should result in a side-wall construction which automatically repairs itself. Aside from reduced maintenance cost, the furnace temperatures could probably be maintained much higher with a resultant increase in combustion efficiency and furnace capacity. Water-cooled construction also permits air control.

Several years ago we discussed the question of air control in connection with gas and it was found by experiment at that time that if the air to the different burners could be absolutely controlled we got better overall results and particularly better operating results. With powdered coal, if we can control the air and put it in where it is needed, whether it all comes in at the burner at light loads or is introduced at right angles is a matter for some one to work out, but the control of the air is an essential element.

As for definite information, the data submitted represent actual tests; and may I emphasize the fact that this was not a brief and hasty experiment. It represented the burning of about 10,000 tons of coal and continuous operation except for those periods when the furnace was taken out of service for changing. It was not taken out at any time for breakdowns.

Small boilers are being operated without any water or air cooling, and the reason is that excess air is used to cool the furnace, or the temperature is being kept down by radiation to the boilers elsewhere.

We know that if the temperatures are high enough to fuse the ash, it is going to fuse. If it does not, there seems to be one answer only, and that is that the furnace temperatures have not reached its fusion point. This may be due to two causes—either there was excess air going into the furnace at certain points, or there was an unusually large proportion of absorbing surface in

the boiler. Either of these things will keep the temperature down. In large installations the ratio of absorbing surface may be changed and whether you will have ash trouble then depends upon design and upon the efficiency, or the rating at which the furnace is operated. In the paper, we referred to the fact that maintenance cost of stokers had a relation to the efficiency at which the stokers were operated. Stokers which have the lowest maintenance cost are usually inefficient. If you don't pay for it in cast-iron, you pay for it in excess air.

Selecting a few of the more important points mentioned by Mr. Crolius, the cost in this case was not any greater than the cost of well operated stoker plants, even though the experimental costs to which he referred were included. The coal was pulverized not to the extreme fineness referred to (85 per cent.) but 60 per cent. through a 200-mesh screen. The fineness and the furnace size have a definite relation. The smaller the furnace, the finer the coal must be to burn completely. That is a question of economics. This furnace, even though the coal was not ground to extreme fineness, operated at approximately 30,000 B.t.u. per hour per cubic foot, which is higher than some one else has referred to.

The reason power consumption on blowers was so high was because the blowers in this case were driven by constant-speed alternating-current motors without any attempt to reduce the power consumption. You will understand that every detail has not yet been attacked in this problem. We intend to make a thorough analysis of the power consumption to the last detail, and determine what can be done to reduce it.

Mr. Crolius referred to the feeders—why spend money for feeders, or fans, to transmit the coal? Feeders are required with the storage-type system. It is a question of foresight to determine whether or not you will use a direct-fired or a storage system, and the system must be selected for the particular job. Instead of half a dozen curves we should have the room covered with curves if we attempted to solve every possible combination. With regard to the superheater construction, where one is required the possibility of installing a superheater in one of the walls should be investigated. Sometimes it introduces complications which might render it unsatisfactory. One of the reasons

for the recommendation of water-cooled side walls is to allow further use of low-head heat. Heat taken from the walls and given to the air and brought back into the high-temperature zone is heat which is eventually utilized at a boiler efficiency of say 80 per cent. If we take the same heat and put it to useful work we get 100 per cent. utilization of the heat; also if air is heated in the walls we do not reserve the possibility of taking some more heat out of the stack gases through air economizers. I do not believe it will be practicable to take the heat from the stack gases and also utilize the air for cooling the walls. It may be that this will be worked out, but we want cool walls and it seems simpler to take heat direct from the stack and feed it directly into the furnace.

Some one, I believe Mr. Rahm, referred to the cost of the water screen. On the basis of developed horse-power, water screens are not a costly addition to the equipment. Each square foot of boiler-tube surface generates several times as much steam as the equivalent amount of tube surface put into the boiler proper. It is more effective.

Mr. Crane referred to this as a test or experiment rather than as operating results. It is because our central-station operation is on the basis of a continuous test. I think engineers should continually be on the alert to keep their entire operation on such a basis that they actually know what they are doing at all times, making it a continuous test. And this test has stretched out over many hours, much coal has been burned, and we believe it represents good operating conditions.

Mr. Blake is exactly right when he said that the advantages gained were due to proper control.

Mr. Henry Kreisinger: Mr. Hobbs, in referring to my suggestion of putting tubes out into the furnace, stated that it would hinder efficient combustion at low rating. Most of us are satisfied with modest ranges of rating, from 150 to about 450 per cent. which is 1 to 3. Mr. Hobbs does not stop with that; he wants to operate his boiler efficiently from 33 per cent. of rating to 400, which is 1 to 12. That is why he objects to that tube being moved into the furnace.

MODERN NATURAL-GAS ENGINEERING

By E. J. Stephany*

The subject of modern natural-gas engineering is big enough to fill several volumes, but it is the intention of the speaker to include only some of the facts of interest to the members of this Society.

Early Days. In the early days of natural gas undoubtedly there was need for engineering ability and the exercise of engineering principles, for then, as now, there were wells to drill and piping to be put in all the way from these wells to the customers' premises. However, I believe I am safe in saying that in those early days no person figured pipe sizes, computed pressure drops, or even knew much about the volumes to be transported. The job was to get the gas, to find the market, to supply the distribution piping, and then to go back and get more gas.

Later Developments. But the services of the engineer were needed and were used more and more. Drilling blindly for gas was almost as foolhardy as searching for a grain of sugar in the sands of the sea with blindfolded eyes. The geologist, with his knowledge of rock and earth formations, of anticlines and horizons, soon came into his own. It was possible to lessen the wild chances of failure, although no geologist has been able to predict the presence of gas beneath the earth's surface with certainty.

It became necessary to plan well-collecting lines and main transportation lines. Measurements were taken at well mouths and the productive capacities of the wells were computed by means of engineering formulæ. Knowing the amount of gas to be transported, the initial pressure, and the allowable pressure drop, the engineer could calculate the size of pipe required.

Pipe couplers came in for a period of development, changes and improvements. The expansion and contraction of pipe with temperature changes had to be considered. The chemical action on the rubbers, the material in the pipe itself, and the various stresses and strains were subject to investigation. In all of these phases the engineer was very useful to the producer and to the distributor.

So also in the town systems—the street mains, the service

*Superintendent Sales Department, Equitable Gas Co., Pittsburgh.

lines and the house meters—there was a period of development. Sound engineering principles came to be recognized and appreciated. Some of us are willing to admit that they were not sufficiently recognized in days gone by.

One of the most important engineering developments was due to the natural law of declining rock pressures and the greater distances over which it became necessary to transport natural gas. I refer to the compressor station, that much-abused part of the natural-gas plant where a part of the population believes that air is pumped into the gas. You will all realize the real need for the application of engineering knowledge to such an important matter as the construction of these many large stations for the collection of gas from many wells and its compression into the main transportation pipe-lines.

The 1917 Peak. But there came a time when the continuous drilling of new wells failed to compensate for the decline in production of older wells; when the peak was reached and when each year showed a falling off in total gas produced. This peak was reached in 1917 practically all through the Appalachian field.

The downward trend of the curve of natural-gas production brought with it many new problems. Both the domestic and the industrial uses of gas had been increasing. It now became necessary to curtail the use somewhere, particularly during the winter months, when the demand far exceeded the supply. The industrial supply was the first to suffer.

Based upon the rule of the sea, "women and children first," industrial plants were forced to discontinue using natural gas on colder winter days. Some industries are now experimenting with oil, powdered coal, producer gas or some other fuel, trying to make this fuel more satisfactory and a better substitute for the unequaled fuel—natural gas.

These times of declining production also have brought very serious problems to the natural-gas companies. With a large investment already made, an increasing investment made necessary for extended searches for new fields, more and larger pipe systems required, and larger operating costs due to lower initial gas pressures, the gas companies found themselves with less gas to sell, but with a larger gross revenue needed. This necessitated higher rates, and higher rates, of course, demand more efficient use. This

problem of more efficient use has been receiving the serious attention of modern gas engineers, and considerable progress has been made in this direction.

Modern Tendencies. Most natural-gas companies are now giving careful thought to the city distribution systems. Modifications in present piping lay-outs by means of high-pressure feeder lines and district governors, new connecting lines, and even changes in main town feeders, are being made to secure more uniform distribution of the gas over the territory. The tendency is to change from pressures of four to six ounces (6.9 to 10.4 inches of water) at the customers' meters to lower pressures. Very likely the pressures of the future will be in the neighborhood of two ounces (3.5 inches of water).

To many it may appear that such a reduction in gas pressure would cause poor service, but this is not the case. With piping of the correct size and with burners correctly adjusted in either case, it has been shown by the United States Bureau of Mines that higher efficiencies can be obtained with the lower gas pressure named. Furthermore, a 100 per cent. pressure variation at six ounces average (from four to eight ounces) is much more serious than a 100 per cent. pressure variation at two ounces average (from one and one-third to two and two-thirds ounces).

All changes in distribution systems are being made with the time in mind when such piping will be used to distribute manufactured gas. Lines must be laid to grade for manufactured gas, smaller volumes will be carried by most street mains, and the pressure drops permissible in piping and meters will be less.

In the field of selling, some changes are also taking place. Most natural-gas companies are now offering expert engineering assistance to their customers and are recommending changes in methods of gas utilization which will result in greater efficiencies, and are helping the user to improve the appliances and equipment now in use.

Some Considerations of Fuel Cost. There has been a general tendency to compare fuels on a basis of thermal value and price. This is inaccurate unless proper consideration is also given to other essentials which determine the suitability of fuel and equipment regardless of price. The quality and cost of finished product resulting from the generation and application of heat may vary

greatly from the ratios of costs per B.t.u. of different fuels. The price of fuel may influence, but it certainly does not determine, the cost of finished product.

The results obtained are produced by a combination of equipment, fuel, and method of operation. These separate elements should be selected with due regard to their suitability to the conditions governing the conduct of the operation as a whole. The engineer is concerned with their ability to produce the desired results, and then with the cost of the operation as a whole.

Right here it might be well to point out that there is a real need for the services of fuel engineers in the various industrial plants. Too often there is an inclination to compare results promised for some modern equipment using other fuels with results obtained by antiquated equipment in use at the time. In comparing results obtained with different fuels, due consideration should always be given to the character of burners and equipment used and to the degree of perfection obtained in the operations.

Some Examples of Fuel Economies. Just to illustrate the fuel economies which have been accomplished by natural-gas engineers in the Pittsburgh district, the following few cases are cited:

Brass Melting. Gas consumption reduced from 325 cubic feet per 100 pounds to 275 cubic feet, and time per melt reduced 15 minutes.

Glass Making. Gas consumption reduced from 70,000 cubic feet per melt to 38,000 cubic feet, and melting period shortened from 30 hours to 22 hours.

Bottle Annealing. Gas consumption reduced from 45,400 cubic feet per lehr per day to 28,700 cubic feet.

Forging. Gas consumption reduced from 1.7 cubic feet per pound of metal to 1.5 cubic feet, and production per furnace increased 50 per cent.

Pottery Firing. Gas consumption reduced from 80,000 cubic feet per day to 60,000 cubic feet, and time interval reduced from 2 hours and 20 minutes to 1 hour and 10 minutes.

Bar Heating. Gas consumption reduced from 1.04 cubic feet per pound of steel to 0.81 cubic feet.

Carbonizing. Gas consumption reduced from seven to six cubic feet per pound of metal, time lessened, labor of packing and unpacking eliminated, and uniformity of product bettered.

Sheet Annealing. Gas consumption reduced from 2600 cubic feet per ton of sheets to 2340 cubic feet.

Bread Baking. Cost of gas reduced from 76 cents per 1000 loaves to 52 cents, and product very much improved.

In the case of brass melting, the shape of the furnace was changed, new burners were relocated, and the size of vents was changed.

In the glass-making operation, a change was made from atmospheric burners and stack draft to air-blast burners. In the third case, ordinary pipe burners in cross ducts underneath the glass lehr were replaced by blast burners near the arch.

In the case of forging, a square furnace with regenerators, and using fan blast for air and steam for distribution, was replaced by a circular furnace with a premixing burner and preheating the material in a second furnace in place of the regenerators.

In the case of pottery firing, the air was preheated by means of recuperators and thoroughly mixed with the gas before entering the kiln.

No changes were made in the bar-heating example other than a change from pipe-nipple burners to modern pressure burners.

For carbonizing, a complete change was made in the method of operation and of handling the material.

No change was made in the sheet-annealing furnace other than the installation of modern burners.

In the case of bread baking, atmospheric burners were replaced by blast burners and a baffle-wall was added to direct the heat to better advantage.

These examples show a variety of uses of natural gas, and different methods of handling each problem. They are intended to show that economies in fuel consumption can be effected and that a wide range of engineering knowledge must be applied.

Combustion Engineering. In order to burn any fuel it is necessary that the proper amount of air be supplied. The oxygen must be thoroughly and intimately mixed with the fuel. This should be the function of the burner. The resultant heat must be properly applied to the work. The uniformity of heat application is important in most cases. The correct degree of heat is definitely established for most operations. Finally, after the fuel is burned

and the work is heated, the loss of fuel and heat through the furnace walls and through the vents must be controlled.

Helpful indicators in determining flue losses are the flue thermometer and the gas-analysis apparatus. The presence of carbon monoxid always indicates incomplete combustion and a loss proportional to the amount of monoxid present.

It is generally realized that the loss through the flues of a furnace increases with the temperature of the exit gases, but the extent of these losses may be better emphasized by the following table. With natural gas completely burned and no excess air present, the percentages lost are as follows:

Flue temperature in degrees F.	Per cent. loss
500	19.0
1000	30.0
2000	53.5
3000	79.7

The effect of excess air on the efficiency of an oven or furnace also seems to be overlooked in many cases. While the quantity of oxygen in the flue-gases may appear to be small, a relatively larger percentage of excess air is present, as shown by the following example, which is for natural gas with complete combustion:

Per cent. of oxygen in flue-gas	Per cent. of excess air present
0.0	0
1.1	5
2.0	10
2.8	15
3.6	20
5.0	30
6.1	40
7.1	50
9.2	75
10.5	100

As an indication of the reduction in efficiency due to excess air, the following table, showing the losses occasioned by different percentages of excess air at a few flue temperatures, is included:

Per cent. excess air	Flue temperature	Per cent. loss
10	500	20.0
10	1000	31.7
10	2000	57.0
25	500	21.0
25	1000	34.2
25	2000	63.0
50	500	23.5
50	1000	39.2
50	2000	73.0
100	500	27.0
100	1000	48.0
100	2000	93.5

The use of insulating materials is of considerable importance, particularly in high-temperature operations. The manufacturer of such materials can usually supply accurate figures by means of which the fuel savings as compared with the cost of installation and maintenance can easily be figured.

The following are a few examples of thermal efficiencies usually obtained in this district. It may be of interest to fuel engineers to compute the efficiencies in their own operations:

Application	Per cent.
Open-hearth furnace	10–16
Annealing steel (heavy work)	18–25
Annealing steel (light work)	15–30
Hardening steel	15–30
Brass melting	8–10
Boilers	50–80
Glass making	3– 5
Forging	3–20

As stated, the design of burners, their location, the gas-supply

lines, and the method of control, are all important. For computing the orifice size of an atmospheric burner, the following formula will be found useful:

$$Q = 1658.5\ AK\sqrt{\frac{H}{d}}$$

Q = orifice capacity in cubic feet per hour.
A = area of orifice in square inches.
K = constant (0.61 to 0.88 for sharp-edge orifice and less for channel orifices, depending upon length of channel).
H = orifice pressure in inches of water.
d = specific gravity of gas (about 0.65 for natural gas).

It may also be well to point out that gas piping is very often inadequate. The lines were originally installed for higher gas pressures in some cases, and more and more furnaces have been added, in many cases without increasing the lines. The following formula will be found useful in computing pipe sizes for usual gas-distribution pressures:

$$Q = c\sqrt{\frac{d^5 \times (p_1 - p_2)}{l \times w}}$$

Q = discharge in cubic feet per hour.
d = diameter of pipe in inches.
p_1 = initial pressure in inches of water.
p_2 = terminal pressure in inches of water.
l = length of pipe in yards.
w = specific gravity of the gas (natural gas = 0.65).
c = constant (1350 for natural gas).

General Service Considerations. The fuel user is interested in the dependability of the present supply, the quantity available, the probable future supply, and the price.

While industrial uses of gas have been curtailed in cold weather, and service in some cases has been unsatisfactory during the winter months, an improvement in conditions can be expected. The adjustment of gas rates, which is inevitable, should result in a lowering of the domestic demand for house-heating and a con-

sequent betterment of service to all classes of gas users. The application of sound engineering principles to the construction of gas-transportation lines and to city distribution piping systems is now resulting in greater uniformity of supply and in greater reliability of service.

Demand and supply cause great and frequent changes in the prices of other fuels. In the case of natural gas, however, there are no such sudden fluctuations, as the gradual depletion of the fields largely controls the cost, and the future price can therefore be foreseen, to some extent at least. Gas companies must endeavor to keep their rates at the point which will enable them to give good service, at the same time aiding their customers to use the gas in the most approved and efficient way.

The life of natural-gas fields, of course, will determine the availability of natural gas. No person can make an absolutely definite prediction, but it is interesting to know that many estimates have been made, and that these start as low as about eight years and run up to thirty years or more.

It is practically a certainty that manufactured gas will be supplied to Pittsburgh after the supply of natural gas is inadequate. This is of particular importance, because gas is undoubtedly the ideal form of fuel and because many industrial plants in cities where manufactured gas is supplied have found that they can use this gas economically because they have applied real engineering to their heating problems.

Conclusion. In conclusion, permit me to say that I have attempted to point out some of the applications of engineering in the natural-gas business and some of the modern tendencies of engineering in this business. Also, I have tried to show where good engineering can benefit the user of natural gas by means of a better product, better working conditions, and more satisfactory fuel costs. I trust that I have added to your interest in the natural-gas business and in the utilization of this ideal fuel.

DISCUSSION

Mr. W. C. Buell, Jr.:* This paper is of considerable interest, and I was glad to have the opportunity of reading an advance copy, for consequently I am able to touch upon several points and to present figures, which ordinarily would not be possible without this advantage.

Mr. Stephany is a natural-gas man and, therefore, for natural gas 100 per cent. as a fuel. Naturally he is enthusiastic as to its value in the field of industrial heating.

There are only a few individuals who will argue that natural gas is other than the "best" fuel. Natural gas is an excellent fuel, but it has three serious disadvantages:

1. Lack of flame temperature as compared to other gases, the liquid fuels, and coal.
2. High cost.
3. Uncertainty of the supply.

The flame temperature of Pittsburgh natural gas is approximately 3800 degrees F. That of a Pennsylvania fuel oil taken at random is 4200 degrees F., and of a gas coal also taken at random approximately the same. In high-temperature processes the flame temperature of natural gas must be increased by the addition of sensible heat in preheated air, which has the effect of increasing the unit calorific value.

The price of natural gas in this district, 50 cents per 1000 cubic feet, locates it as a high-priced fuel. Some price concessions have been made to large users in the last couple of years for gas used from April 1 to October 31 in order to find a market for normal production. That such a price reduction is necessary is sufficient proof that users in general find that substitute fuels, properly applied, give results at least equally good. During recent years the uncertainty of the supply has forced fuel users to look for substitute fuels, which quite generally have been other "fixed" fuels, and combination natural gas and other fixed fuel systems have been generally installed; but in many cases where such systems are used the substitute fixed fuel is continuously used even when natural gas is available.

*President, Buell, Scheib, Mueller, Inc., Pittsburgh.

Mr. Stephany states that "Some industries are now experimenting with oil . . . or some other fuel, trying to make this fuel more satisfactory and a better substitute for the unequaled fuel—natural gas." From an intimate 10-year experience in this district with fuels and furnaces, I am convinced that the day has passed for the general use of natural gas in the industries unless new fields of large capacity are found within a reasonable distance of the city, and unless the volume of gas from these fields be so great as to reduce present prices materially.

Mr. Stephany states that the natural-gas companies are now offering their users engineering service in order that a more economic use may be made of natural gas. This is a most excellent service, but again it should be borne in mind that the engineer in the service of a natural-gas company is too greatly prejudiced to make this service of the greatest economic value.

I am glad that Mr. Stephany has touched upon the subject of the habit of comparing results obtained in the use of antiquated equipment with modern equipment. After many years it is finally being recognized that the design of fuel-consuming equipment is of a highly specialized and technical order and that new equipment properly designed will frequently show unbelievable overall economies as compared with equipment constructed by the older method.

Mr. Stephany notes a number of actual results. To some of these I can add other figures which may prove of interest; all comparisons being based on calorific equivalents. He cites the case of a forging furnace with the fuel consumption reduced to 1.5 cubic feet of natural gas per pound. There are a number of furnaces in a shop in this city where they produce their metal on an average of less than 25 gallons of oil per ton. At 25 gallons of oil per ton the gas equivalent would be 1.4 cubic feet per pound, and the writer has figures from a forging investigation which extended over two years, using coke-oven gas as a fuel, where on a week's run in a small furnace and producing approximately 250 tons of forgings the natural-gas equivalent was 0.82 cubic foot per ton. Again, under bar heating, in which 0.81 cubic foot is given as the minimum amount of fuel, I can offer as comparison a furnace in this class of work (natural-gas fuel in Wooster, Ohio) operating on 0.75 cubic foot per pound, while in this vicinity our organization has designed a coal-fired furnace of a new type which

is operating on the natural-gas equivalent of 0.87 cubic foot per pound.

On the subject of operating efficiencies, Mr. Stephany credits the open-hearth furnace with a 10 to 16 per cent. performance. A number of years ago there was a series of tests covering over 450 heats, conducted by one of the large steel companies* in this vicinity using natural-gas fuel. This series of tests showed an efficiency of 26.3 per cent., and as this figure is so very much at variance with Mr. Stephany I have abstracted the balance figures on a basis of per ton of steel as follows:

Heat of combustion		5,720,000
In steel	1,480,000	
In slag	323,000	
Reduction of ore	162,000	
Decomposition of limestone	101,500	
	2,066,500	
Deduct heat in hot metal charge	566,000	
	1,500,500	

or 1,500,500/5,720,000 = 26.3 per cent.

The foregoing figures, which were taken more than 10 years ago, indicate 5,720,000 B.t.u. in the fuel per ton of metal produced. Improvements in furnace design have since materially reduced this.

Further, in reference to the open-hearth furnace, we expect to make steel from all cold metal with from 40 to 45 gallons of oil per ton, which is from 30 to 35 per cent. efficiency.

There is a large billet furnace in this district, using coke-oven gas as a fuel, that for long periods has been claimed to operate at thermal efficiencies better than 60 per cent.

Other figures of a similar nature might be given for other classes of work, but as the figures given are general, and I can cite only specific cases, other results are omitted.

*Fuel Possibilities in Steel Making," by William Whigham. (In Year Book of the American Iron and Steel Institute. 1913, pp. 295-311.)

With good furnace design the following would appear to the writer to be a fair comparison of fuel costs. With natural gas at 50 cents per 1000 cubic feet, fuel oil should compete satisfactorily on a cost basis when fuel oil is selling at seven cents per gallon or below; and with natural gas at 30 cents, fuel oil should compete at 4.75 cents per gallon or below. To cite the case of the furnace heating bars, mentioned above—which is delivering on less than 150 pounds of coal per ton of metal—with coal at its present delivered price of $2.50 per ton, it would be necessary that gas sell at 13 cents per 1000 cubic feet to give equivalent cost performance.

Mr. Stephany mentions the use of insulating material in high-temperature operations, and by high-temperature operations I presume he means furnaces operating at temperatures in excess of 1700 or 1800 degrees F. I eliminated the use of insulating material in connection with high-heat furnaces a number of years ago, and I think furnace designers in general are not using it. With high-temperature operations there must be a considerable heat flow through the walls, which, if prevented by the use of insulating materials, causes the inner face of the fire-brick lining to soften or melt and be destroyed, and this continues until the wall reaches a point of equilibrium at which sufficient heat flows through the walls to keep the inner surface of the brick below the softening point.

Mr. A. E. Blake:* Having read an advance copy of Mr. Stephany's paper, I thought it would be of interest to present some data which I have compiled and found to be of great help in explaining the relative values of different gases. The first two tables are self-explanatory, and anyone with a little knowledge of gas reactions with respect to volume changes, plus an accurate analysis of the gas fuel, can apply the method to any industrial gas and compare it with others.

*Pittsburgh Representative, U. G. I. Contracting Co.

TABLE I. COMBUSTION DATA ON NATURAL GAS

COMPOSITION

$CH_4 = 84.0\%$	
$C_2H_6 = 15.8\%$	Specific gravity 0.631
$CO_2 = 0.2\%$	B.t.u. 1126
100.0%	

$$\underset{(0.84)}{CH_4} + \underset{\substack{(1.68)\\(8.038\text{ air})}}{2\ O_2} = \underset{(0.84)}{CO_2} + \underset{(1.68)}{2\ H_2O}$$

$$\underset{(0.158)}{2\ C_2H_6} + \underset{\substack{(0.553)\\(2.646\text{ air})}}{7\ O_2} = \underset{(0.316)}{4\ CO_2} + \underset{(0.474)}{6\ H_2O}$$

8.038
2.646

10.684 volumes of air required to burn one volume of gas.

$10.684 + 1 = 11.684$ cubic feet of theoretical mixture per cubic foot of gas.

$\frac{1126}{11.684} = 96.37$ B.t.u. per cubic foot of theoretical air-gas mixture.

PRODUCTS OF COMBUSTION

a.	CO_2	in gas	0.200	
		from CH_4	0.840	
		from C_2H_6	0.316	
				1.356
b.	H_2O	from CH_4	1.680	
		from C_2H_6	0.474	
				2.154
c.	N_2	in air	8.451	8.451
				11.961 cubic feet per cubic foot of gas.

$\frac{1126}{11.961} = 94.14$ B.t.u. per cubic foot of products of combustion.

$\frac{2.154}{11.961} = 0.1801$ or 18.01 per cent. H_2O in products of combustion.

TABLE II. COMBUSTION DATA ON BLUE WATER-GAS

COMPOSITION

$CO = 43.5\%$	Specific gravity	0.559
$H_2 = 47.3\%$	Specific heat	0.45
$CH_4 = 0.7\%$	Heat content	302 B.t.u.
$CO_2 = 3.5\%$	Reaction temperature	
$O_2 = 0.6\%$	(theoretical)	3470° F.
$N_2 = 4.4\%$	(O_2 in air taken as 20.9 per cent. by volume.)	
100.0%		

$$\underset{(0.435)}{2\,CO} + \underset{\substack{(0.2175)\\(1.0407\text{ air})}}{O_2} = \underset{(0.435)}{2\,CO_2}$$

$$\underset{(0.473)}{2\,H_2} + \underset{\substack{(0.2365)\\(1.1316\text{ air})}}{O_2} = \underset{(0.473)}{2\,H_2O}$$

$$\underset{(0.007)}{CH_4} + \underset{\substack{(0.014)\\(0.067\text{ air})}}{2\,O_2} = \underset{(0.007)}{CO_2} + \underset{(0.014)}{2\,H_2O}$$

1.0407
1.1316
0.0670
2.2393 gross volume of air to burn one volume of gas.

(Correction for oxygen content in blue gas, 0.6 per cent. $O_2 = 0.006$ volumes, equivalent to 0.0287 volumes of air.)

2.2393
0.0287
2.2106 net volume of air to burn one volume of gas.

$2.2106 + 1 = 3.2106$ cubic feet of theoretical mixture per cubic foot of gas.

$\frac{302}{3.2106} = 94.06$ B.t.u. per cubic foot theoretical air-gas mixture.

PRODUCTS OF COMBUSTION

a. CO_2 $\begin{cases} \text{in gas .... } 0.035 \\ \text{from CO .... } 0.435 \\ \text{from } CH_4 \text{ .... } 0.007 \end{cases}$ 0.477

b. H_2O $\begin{cases} \text{from } H_2 \text{ .... } 0.473 \\ \text{from } CH_4 \text{ .... } 0.014 \end{cases}$ 0.487

c. N_2 $\begin{cases} \text{in air} \dots\dots\dots\dots & 1.748 \\ \text{in gas} \dots\dots\dots\dots & 0.044 \end{cases}$

1.792

2.756 cubic feet per cubic foot of gas.

$\frac{302}{2.756}$ = 109.58 B.t.u. per cubic foot of products of combustion.

$\frac{0.487}{2.756}$ = 0.1767 or 17.7 per cent. H_2O in products of combustion.

TABLE III. COMPARISON OF GASES

	Natural gas	Blue gas	Cold clean coke producer gas
B.t.u. per cubic foot	1126	302	127.2
Cubic feet of air for theoretical combustion	10.684	2.21	0.938
B.t.u. per cubic foot of theoretical air-gas mixture	96.37	94.06	65.5
Cubic feet of flue-gas per cubic foot of gas from theoretical air-gas mixture	11.961	2.762	1.743
B.t.u. per cubic foot of flue-gas	94.14	109.6	73.0
Per cent. H_2O in flue-gas	18.01	17.7	7.16
Cubic feet per million B.t.u	888.1	3311.0	7.775
Reaction temperature	3370° F.*	3470° F.	2730° F.

(O_2 in atmosphere = 20.9 per cent. by volume.)

In Table III, the results of the first two are tabulated, together with those from a sample of producer gas. Going through Table III, it should be very apparent that the heat value for any gas is of very slight importance as a factor in determining the value of that gas as a fuel. This is due to the chemical nature of the constituents, whether these are molecules of simple constitution, such as hydrogen or carbon monoxid; or somewhat complex, if by complex we mean one which contains two different elements which will unite with oxygen. In such cases the volume of the products of combustion will exceed the volume of combustible mixture, while in the case of blue gas and producer gas, the volume of combustion products per cubic foot of gas burned is less at equal temperatures and pressures than that of the combustible mixture. It can be seen from Table I that a single volume or molecule of methane needs two volumes or molecules of oxygen,

*Approximate. Not computed.

while carbon monoxid or hydrogen needs only one-half a volume or molecule.

Gas fuel is unlike any other commodity sold by public utilities, because it will not function without the use of air. This is entirely different from water, electric and steam-heating service. It is this air requirement and its difference in the case of different gases that is very commonly overlooked, but which makes all the difference in the world between the results expected and those actually gained in looking into a case of this kind.

In reality, the so-called B.t.u. content of a gas is chiefly a factor in determining sizes of conducting pipes, or of pressure at which a gas should be carried in a pipe of a given size.

The theoretical concentration of heat units per cubic foot of products of combustion resulting from burning a theoretical mixture of gas and air, reduced to standard conditions, is very useful in determining whether a gas is high or low grade. While there may be any number of possible values between those given, and some lower, I generally consider a value below 90 B.t.u. as being the minimum for a high-grade gas. All the high-grade gases with which I am familiar give values which are regularly higher than this. In the same way, gases with reaction temperatures above 3300 degrees F. can be considered high grade. The reason why producer gas does not compare favorably with the others is in the fact that, like the particular sample given where the combined nitrogen and carbon dioxid content is 60.8 per cent., inactive gases must be heated up along with the elements actually taking part in the reaction and the nitrogen in the air for combustion. The effect is the same as in the cases of use of excess air which have been emphasized by Mr. Stephany.

Speaking of gas pressures in the lines, I suppose most of you know that in cities where artificial gas is used, two ounces is the standard, and it seems to have been found the optimum pressure for distribution with the object of saving as much leakage as possible. Whether all the pipes in the Pittsburgh district are designed for supplying gas at two-ounce pressure or not is hard to say just now.

Mr. Stephany made a very timely point regarding the habit of a good many industrial users of gas, of judging the performance of other fuels by their ordinary experience with gas; not

attempting *first* to see what is the best that can be done with gas. Recently I got hold of a few figures on forging which might be of interest in that connection. These showed that in a slot furnace, for heating rod ends, very well designed and the test very well made, using fuel oil, and an expensive recuperator, the efficiency obtained, as nearly as could be calculated, was 7 1/3 per cent., assuming that the ends of the rods were heated to 2000 degrees F. Assuming that they were heated to 1800 degrees, the efficiency—that is, the amount of heat actually required or contained in the steel at the temperatures stated, divided by the number of B.t.u. supplied as fuel—is 6.5 per cent. The same furnace, adapted to burn a theoretically proportioned and homogeneous mixture of natural gas and air, will easily show an efficiency of 15 per cent. without any preheating at all. A furnace designed for the same duty, using gas only, will show an efficiency of 19.4 per cent. The slot in the latter furnace is not as wide, and the furnace is faster working. Insulation is used and there is no particular difficulty in maintaining the interior. The cost of the gas furnace to do that work, in one case using the smallest furnace that is designed to produce the same tonnage, is $265, and of the furnace that more nearly compared with the oil furnace, $350. I tried to find out the cost of the oil furnace complete, with burner and recuperator, and the nearest figure I could get on it is about $1000.

In this district it is frequently necessary to design a furnace to provide for oil as an auxiliary fuel. That is a pretty good thing to do, from past experience with natural gas. But when you do that, in order to be able to operate with oil, if you want to use modern gas equipment at the same time and get the best results, the furnace chamber must be larger for the benefit of the oil. In spite of anything you can do, you will have a considerable flame, and to get efficient operation the flame ought to be confined in the furnace as much as possible. The case just cited shows a difference between 19.4 and 15, or 4.4 per cent. gain in efficiency, when oil firing does not have to be provided for. The gain is $\frac{4.4}{15}$, or 28.3 per cent., in favor of the furnace designed for gas only; so, if you have to provide oil as an auxiliary, but can use gas almost the year round, you have to use about 20 per cent. too much gas for the privilege of having oil as a stand-by.

Mr. Buell made some remarks about flame temperatures, 3800 degrees for natural gas, 4200 degrees for oil. Were these calculated for preheated air?

Mr. W. C. Buell, Jr.: No.

Mr. A. E. Blake: I should like to see those figures, because I have had the impression that natural gas with about 15 per cent. ethane and the remainder methane has a flame temperature of 3350 to 3370 degrees. I do not recall flame temperatures of oils which I have seen reported, but I am under the impression that they are lower than Mr. Buell stated, when no preheating is used. I do not think it is any drawback if the gas does not come up to the oil. You are limited anyhow by the softening temperature of the lining of your furnace, and there is no sense in burning the refractories out of the furnace every two weeks just because you can get a hotter flame than is needed to do the work. The cost of furnace lining may make up for the seeming cheapness of fuel, if oil ever should be any cheaper, compared with gas properly applied. Then again, with oil you have a fuel which is in a liquid state, and before it burns it must vaporize. In fact, without vapor or gas you can have no flame. Being a complex mixture of hydrocarbons, it will take some time, relatively long, for the oil to vaporize and "crack." and then oxidize. Compared with fuel oil, the methane of natural gas is a relatively simple substance, and you can expect very short zones of combustion, and that is what you actually get when burning a homogeneous mixture with air. When you take some of the manufactured gases, such as blue water-gas, about 50-50 hydrogen and CO, you have simple substances, hence the minimum possible changes are necessary preliminary to combustion. The theoretically higher flame temperature of oil is detracted from by the fact that, due to its complex composition, combustion is not as rapid as with gas, and actual combustion temperatures with oil do not come as near to the theoretical as they do in the case of gas. Theoretical flame or reaction temperatures are well and good to take note of in judging different fuels, when they are widely separated in quality, as cold producer gas and blue gas are; and, since values for this theoretical figure are arrived at after several exceptions have been made, when they

are in excess of 3500 degrees F. they ought not to have undue weight.

I do not agree with Mr. Buell's statement that 50 cents is too high a price for natural gas. I think we can afford to use natural gas in a great many industrial processes in Pittsburgh, if we have to pay as high as 70 or 75 cents if a constant supply is assured. In this investigation of which I have been giving you some results the oil was 6.5 cents.

It seems to me that we can get down to an equal basis and get much more out of our discussions if we state thermal efficiencies, if we can ascertain them. There are a good many cases where it cannot be done, as in glass melting. Those open-hearth tests were very interesting, indeed. I wonder how the cost of maintaining the roof and throats compared with ordinary good practice.

Coming to the elimination of insulation, I cannot see that for a minute. I think if you bond your refractories carefully, prevent flame from licking them, and control the combustion as it *can be done,* with gas at least, you will not be bothered very much with your furnace lining. It will hold up a great deal better with gas than it will with oil. The plea for elimination of insulation in furnaces is no argument in favor of any kind of fuel or firing practice which demands it.

Where we are dealing with high-temperature work of this kind, we find it possible to outline an interesting set of conditions for commercial equilibrium.

The management seeks heat at the lowest overall cost, f.o.b. the product, so to speak. It is up to the management, therefore, to observe the factors of expense and stack them in the best way to secure the lowest figure. Several of the items are already in common use, and it is by such discussions as this that we can and should popularize the others.

The familiar items are: (1) cost per B.t.u. delivered at the plant; (2) cost of applying this stored heat to work; (3) investment costs in the case of each fuel; (4) costs of storage, leakage, purchase, insurance, demurrage, and numerous other items not always reckoned; (5) relative cost of furnaces and firing apparatus.

The items not as commonly observed are: (1) relative thermal efficiency; (2) relative life of furnace lining; (3) com-

parative rate of production; (4) relative damage from scaling, decarbonizing, or other chemical effects; (5) comfort and satisfaction of employees; and so on.

You all agree, I think, that the first group can be, and generally is, more or less well looked after by ordinary, non-technical purchasing agents and production men; also, that if the second group is not looked after with proper care, the attention paid in the first case can be completely wasted.

It is strange these days, with fuel bills stepping nearer and nearer the front rank among manufacturing costs and totaling the enormous annual figures that they do, that so many concerns are content to abide by the guess-work of men not qualified to be judges of fuel and its application. There are a few signs of an awakening, and I know of two prominent concerns which have each recently invested in the permanent services of the best expert fuel man available in each case. One case has resulted in what is admitted by all qualified to judge to be the most satisfactory and economical sheet mill to be found, and a saving each year of many times the salary invested. The second case will undoubtedly show similar results. I only hope that the policy will become general. Then a jibe which recently appeared in one of the journals, reading as follows: "Dozens of great corporations continue to pay $100,000 a year for legal advice and $10,000 for scientific guidance,"* will no longer hold. I do not know many concerns which pay as much as $10,000 for the kind of service of which I am speaking.

To the layman, an explanation of the factors in actual firing practice is bound to call to mind things like Holmes's description of the "One-Hoss Shay." I can venture a few remarks which have not been touched upon here, which not only seem reasonable, but which have been proven so.

It is desirable, in fuel heating, to have the zone of combustion as small as possible; in other words, with the least flame, or without any flame, as we commonly think of it. Flame denotes combustion, but it is not a means or an essential for heating. If combustion is complete near the burner, the products of combustion, which really carry the liberated heat, have a relatively long

*Gas Age Record, v. 51, p. 324.

time to remain in the furnace while on the way to the flue. Hence the shorter the flame or combustion zone, the greater the opportunity for heat to be available from combustion products to the steel, if we assume steel is being heated. With a flame extending from burner to flue hole, such as many people suppose to be the correct thing, large percentages of combustion products are not formed until they are about to enter the flue; so the heat which they contain is literally thrown away. It is often contended that flame radiation is a very useful factor in heating. In reality it does as much harm as good. A white flame certainly does radiate much heat; but while the charge is benefiting beneath, the roof or other portion of the lining is being ruined, because flame radiations usually sought are at a temperature above the fusion point of ordinary standard fire-brick. It is better to take advantage of a short combustion zone as just suggested, and be content with the very large amount of radiation which is always available from the furnace walls while they are maintained at a temperature which will not harm the bricks. For instance, this procedure would allow a radiating temperature in the walls as high as 3000 or 3100 degrees with first-quality refractories, and this is certainly high enough for any practical purpose in the smaller types of furnace which I am thinking of; as for instance, forging, where the steel needs to be heated to temperatures between 1800 and 2400 degrees.

Absence of flame reduces the necessary volume of the furnace and, therefore, the area of brick surface upon which wall losses by conduction must be maintained. In the case of the oil-fired furnace, which I referred to at first, fired in the best manner with gas, the percentage of heat lost through the walls is 30 per cent. of the total amount supplied. By minimizing the combustion zone, burners can be so directed to the furnace interior that products of combustion are given a chance to lose enough heat to the work to prevent injury to the lining when they do come in contact with it.

Mr. Stephany has already called attention to the detrimental effects of excess air or excess fuel. In small high-temperature furnaces the oil people demand excess air, and, if it is not used, the length of flame will be beyond all reason. The object is familiar to the chemist who knows that to speed up any chemical change he should add an excess of the reacting substance needed

to enable the change to proceed to the final consumption of all the material to be consumed—in our case the fuel. This may catch the layman by comparing the results to be gained by twenty policemen chasing and fighting with a burglar, instead of one. Excess air is wholly unnecessary in burning gas. Gas can be burned so as to avoid any flame whatever (where flame is understood in the ordinary sense), and the control over gas burning is quantitative; so that the composition of the flue-gas can be kept constant at all times. Anyone denying these facts would expose his lack of information as to past and current accomplishments in the control of combustion. Free oxygen can be eliminated completely from the furnace chamber, or it can be admitted purposely to give some desired degree of oxidizing power. On the other hand, a constant carbon monoxid content can be maintained. With oil we have flame, and plenty of it. It is often necessary to supply large fore-chambers in which a good deal of the combustion is required to take place, so that the heat generated can be available in the main furnace chamber without incurring so much of the waste as would otherwise be necessary, for the reasons just stated. These fore-chambers, however, absorb heat which is conducted through their walls and occasion much loss. In addition they are bulky and costly, and are often operated so that they must be frequently relined. In small oil furnaces it is common to find free oxygen and free carbon monoxid and often unburned hydrocarbons. This is due to the nature of the oil, which requires so much more time to decompose and to be oxidized thereafter.

Gas burners can be adjusted to supply the proper amount of air, and the control of this factor is removed completely from the duties of the operator, who is supplied with a single valve by the use of which he can cause slow or rapid heating as easily as one can regulate the flow of water from a faucet. Such refinements, in reality simplifications, in firing control have not been attained with oil, coal, or any other fuel.

If natural gas had not been literally thrown away during the years when it was cheaper and available the year round (and as it still is in hundreds of instances), this meeting probably need not have been held. Any mechanic who has not been able to arrange a few pieces of plumbing for an oil burner which would beat natural gas as it has been used deserves the lowest sort of rating.

Much real gray matter has been expended upon oil burners, and to them oil usage owes everything. The same class of engineering talent devoted to gas burning, however, has placed the latter where it has always belonged—at the head of the fuel procession.

MR. E. O. MUELLER:* I should like to ask the speaker three questions which are unrelated to each other.

Some years ago I had occasion to take a hand in designing a very large coke-oven plant in this district. I have been told since that the same large company supplies to one of the natural-gas companies, a coke-oven gas which is mixed with natural gas, and I should like to find out whether that is correct.

Second, the speaker mentioned a formula which he used, and I was wondering how this formula compares with Pole's and the so-called "Pittsburgh" formula.

Third, whether the speaker could give us an idea of the construction and material used in the recuperator of which he spoke.

MR. W. IRWIN MOYER:† The speaker mentioned the matter of future gas supply for this district. I rather think we will have natural gas in Pittsburgh for quite a long time. In the future, however, the domestic consumer will have to pay his share—an obligation he has heretofore shirked. The industrial consumer has helped to pay for the gas which the domestic consumer has used. Producing companies have been forced to carry an extra heavy equipment to take care of their winter load for the benefit of the domestic consumer, and due to that load they have maintained a larger number of wells and larger field equipment of all kinds, more compressing stations, heavier transmission lines and a larger overhead. All this has been primarily for the domestic consumer.

As to the possibility of newer fields, I do not think there will be any in this district—that is, in the Appalachian field. The companies producing in the Pittsburgh district have explored every area of any considerable size that gives promise of yielding gas within the limits of feasible transportation to this city. They have gone as far south into West Virginia as to meet the producer coming up from the other side around the Charleston district, and

*Sales Engineer, Sterling Equipment & Supply Co., Pittsburgh.
†Geologist, Philadelphia Co., Pittsburgh.

have gone as far north as to meet the producers of the Buffalo and Bradford districts. Going east, there is no gas to be found unless it be in the mountains, which is unlikely. Going west, we get into the Cleveland field and the Columbus field and the other Ohio towns that take their share. On every side we are hemmed in by the other fellow. Fortunately, the Pittsburgh companies have previously spread out considerably so that they have many open spaces to drill and can continue to expand the present fields; but, as for new fields of any great size, I believe they are things of the past.

There has been much discussion regarding the possibility of developing deeper sands in this vicinity. If that were so, it would mean a revival of the ancient natural-gas conditions around here, and, if the supply were of the same proportion as in the old days, we should have cheap industrial gas here for a long time. Unfortunately, that is very unlikely within the Pittsburgh district; it is not impossible, but it is highly improbable. I base this on the records of what has been done in the past. There have been eight deep wells sunk in this district and only one has found gas, and that only a small quantity. The cost of drilling wells to the lower sands which exist here (the Oriskany, or possibly the Clinton below it) would be so great that to produce gas from these sands would mean producing it at a cost with which manufactured gas can compete, and probably advantageously. You cannot drill a well to that depth for less than about $100,000, and the cost of a failure, or an unproductive well, would be extremely great and the chances of profit correspondingly hazardous. But, basing our assumption upon the fields which we have at present, I think we shall (and I mean the companies in the Pittsburgh district) maintain a good supply for a long time. I am rather optimistic regarding this. The rock pressure, which after all gives a good index of reserves (your production will decline as your rock pressure), declines about as a hyperbolic curve. I think the decline of the fields as a whole will follow about the same curve as the decline of the individual well. Production of the individual well begins very high for the first few weeks or months, and rock pressure is also high. After a short time the rock pressure curve declines and gradually straightens out and continues at a low ebb for a long time.

To-day there are in this district producing wells in which the rock pressure has fallen off only slightly in the last five or ten years. They are small wells, but they show very little decline in production from year to year. Of course, such wells are exceptional, because it is not ordinarily profitable to operate these very small producers, and they are generally abandoned before they reach this stage. Whatever the initial production of a well may have been, the decline at the end of the life of a well is slow and gradual, and I believe the decline of the rock pressure of the fields, as a whole, will be the same. It has fallen off very distinctly in the past ten years, but I think it will flatten out, following a hyperbolic curve, and we shall have a long period of production in this district—not as much as we used to have, of course, but sufficient to supply the needs of the consumer, properly regulated.

MR. H. M. HENRY:* Natural gas in this district is a cheap fuel at 50 cents per 1000 cubic feet. As a matter of fact, it is so cheap that in the past very little attention has been paid to its more efficient utilization. However, as pointed out by Mr. Stephany, steps have already been taken to bring about greater economies in the use of natural gas and this will be given more attention in the future.

Natural gas in this district compares very favorably with fuel oil on a B.t.u. cost basis. Thus, with fuel oil costing from four to five cents a gallon, it will cost in the neighborhood of another cent a gallon to cover insurance, interest, and depreciation on storage tanks, pipe-line maintenance, pumping charges, demurrage, etc.; therefore we can safely figure six cents a gallon for oil delivered to the furnace. Ordinary fuel oil contains 144,000 B.t.u. per gallon. Thus, 1,000,000 B.t.u. of fuel oil cost 42 cents. Natural gas contains approximately 1100 B.t.u. per cubic foot, and, selling at 50 cents per thousand, 1,000,000 B.t.u. in the form of natural gas cost 45 cents. Large users of natural gas are able to buy 1,000,000 B.t.u. as low as 36 cents, so, on an average, natural gas is as cheap as fuel oil on a B.t.u. cost basis.

However, we do not want to judge fuels from the cost per million B.t.u. We must consider the efficiency of utilization, and

*Manager, Pittsburgh Branch, Combustion Utilities Corporation, Pittsburgh.

when we speak of efficiency we do not mean necessarily the ratio of heat utilized to the heat supplied, but the other and in some cases more important factors, as quality of work, production, etc. To take up a discussion of the various efficiencies of utilization of fuels would involve a complete analysis of all the factors which enter into the efficiency, such as the nature of the fuel, whether it is a solid, liquid, or gas, amount of inerts present, quantity of air required for combustion, and flame temperature. Each one of these plays an important part in the efficiency, and all should be considered before we assume one fuel will be more efficient than another.

I will touch briefly on the effect of flame temperature on the efficiency. We all know that the flame temperature is one of the most important factors affecting the efficiency of utilization. However, we do not want to conclude that just because one fuel—say fuel oil—has a higher theoretical flame temperature than natural gas, it can be more efficiently utilized. The possible development of the theoretical flame temperature must be considered, and the factors which tend to lower flame development are the speed of flame propagation, which depends on the mixture as well as the combustible constituents, the amount of air required for *complete* combustion dissociation, etc.

Every one will concede that fuel oil must be gasified before it can be burned, so it is not possible to obtain as thorough a mixture of air and oil as of air and a gaseous fuel. Second, the amount of excess air required to burn natural gas will be less, since we can obtain a more intimate mixture. Dissociation plays a very small part in flame development until we reach temperatures above 3400 degree F., and most of the fuels used have a theoretical flame temperature below 3500 degrees F., using cold air for combustion. However, when hot air at a sufficiently high temperature is supplied, all fuels have a higher theoretical flame temperature than 3500 degrees F. Thus, while theoretically the fuel which has the highest theoretical flame temperature (when burned with hot air) is more efficient than some other fuel which has a lower theoretical flame temperature (assuming that the theoretical flame temperature of this fuel is considerably higher than 3500 degrees F. and the theoretical flame temperature of natural gas burned with air at 1500 degrees F. is higher than 3500 degrees

F.), we find that *practically* the fuel with the higher theoretical flame temperature does not have an advantage over the fuel with the lower flame temperature, since, when we raise our products of combustion to 3400 or 3500 degrees F., dissociation steps in and limits the practical temperature which we can develop. This places all fuels which have a *theoretical* flame temperature above 3400 or 3500 degrees F. on the same footing, in so far as a comparison can be made from the theoretical flame temperatures.

While, as pointed out, natural gas compares very favorably with fuel oil on a B.t.u. cost basis, and therefore should have little difficulty in competing with fuel oil, we find that artificial gas costs considerably more than fuel oil on a heat-unit basis. Yet, in spite of this fact, the artificial-gas industry has increased over 100 per cent. in the last ten years, and a large percentage of this increase has been brought about by replacing fuel oil in heating operations. The reason for this is that artificial gas has always been expensive to make, and therefore its efficient utilization has been an important factor in securing industrial business. Thus we find that wherever artificial gas is used in industry it is efficiently used.

The average B.t.u. value of artificial gas distributed to-day is 560 B.t.u. per cubic foot. Hence, with artificial gas selling for 80 cents per thousand cubic feet, 1,000,000 B.t.u. cost approximately $1.45, or slightly over three times the cost of 1,000,000 B.t.u. of fuel oil or natural gas. The above rate of 80 cents is the industrial rate for artificial gas in Chicago, and, although fuel oil is cheaper in Chicago than in nearly any other city in the United States, the Peoples Gas Light & Coke Company has been able to sell a tremendous volume of industrial gas.

To cite specific cases where and why artificial gas has been able to displace cheaper fuels the following facts are submitted. Artificial gas in a certain city sells on a sliding scale of from 70 cents to as low as 40 cents per thousand cubic feet. The B.t.u. value is 580 B.t.u. per cubic foot. Thus 1,000,000 B.t.u. cost 71.4 cents. Fuel oil was selling to a certain plant in that city for 4.5 to 5 cents per gallon delivered, or 6 cents at the furnace. A million B.t.u. of oil therefore cost 42 cents, or slightly more than half the cost of artificial gas. The gas company approached this plant with a proposition for the conversion of its plant to the

use of gas. The company was so favorably impressed that it agreed to run comparative tests on an oil furnace and a gas furnace doing the same work, and determine the relative advantages of each fuel. The following is a summary of tests conducted over a period of one month by the plant engineers:

Efficiencies of furnaces were 6 to 10 per cent. with oil, and 18 to 26 per cent. with gas.

Efficiencies are figured on the gross heating value.

An increase in production of 12 per cent. by use of gas over use of oil (though some of the men objected very strenuously to a change of fuel). Scale from the gas furnace showed 36.6 per cent. less than that produced in the oil furnace. Reduction of 31 per cent. in the number of rejections of pieces, due to pits in stock not being filled out, etc., as a result of using gas.

The report concludes with the following paragraph:

"This report has been made with the idea of representing the facts just as we have found them, without entertaining any biased opinion on our part or without the intent to strictly criticize the general opinion on this subject."

I want to touch briefly on how it is possible to bring about a lower fuel consumption in various heating operations. As you know, the majority of heating operations are carried on with temperatures ranging from 1200 to 3000 degrees F. At these temperatures, from 25 to 75 per cent. of the heat in the original fuel is carried out in the waste furnace gases. It is evident, therefore, that unless we recover this heat and return it to the furnace or use it for some other purpose, we must be satisfied with very low thermal efficiencies on our heating operations. This heat may be recovered by one of three methods: (1) by preheating the material; (2) by preheating the air and gas, or both, used for combustion; (3) by generating steam in waste-heat boilers. I will not attempt a discussion of these various methods, but will state briefly that there are cases where the first and third methods cannot be used advantageously, and for that reason the second method should be used. I will hurriedly give you some of the results which have been accomplished in a few industrial heating operations.

On brass-melting furnaces of the reverberatory type, by means of recuperation, a 2000-pound charge of brass is melted in from 50 to 70 minutes, with a fuel consumption of 275 cubic feet

of 600-B.t.u. gas per 100 pounds of metal. The metal loss on 85:5:5:5 brass is less than one per cent. Assuming that natural gas is equally as efficient as artificial gas, 100 pounds of brass could be melted with 145 cubic feet of 1000-B.t.u. gas. The average practice in this district is from 300 to 500 cubic feet. Thus the manufacturers melting brass in this district are using from two to three times as much fuel as they should.

In crucible melting, a 300-pound charge, by the use of recuperation, is melted in one hour, the metal being superheated to 300 degrees F. per 100 pounds, the fuel consumption being 374 cubic feet of 600-B.t.u. gas. Reducing this to a basis of natural gas we find that 200 cubic feet of natural gas would be required for the same operation. How many foundries are obtaining these results? My observations thus far have shown that the general practice (without any superheat to speak of) is from 400 to 700 cubic feet per 100 pounds.

In forging operations, by the use of recuperation or regeneration, efficiencies have been doubled and in a number of cases trebled. Steel forgings being produced with a gas consumption of from 3000 to 5000 cubic feet per ton, artificial gas of 560 B.t.u. being used.

On carbonizing operations (temperature ranging from 1400 to 1700 degrees F.), a reduction of from 30 to 40 per cent. in fuel has been obtained by the use of recuperation.

In general, it might be stated that fuel savings as high as 50 per cent. are easily possible by the use of recuperation or regeneration over the most efficient furnace in which no attempt is made to recover the waste fuel, and in a majority of cases the savings will be considerably greater.

You are, no doubt, interested in what you will have to pay for the manufactured gas which will be used when the natural gas has given out. I might state that while the artificial gas supplied will undoubtedly cost more per 1,000,000 B.t.u. than natural gas now costs in the home or the small industries, the monthly gas bills will be only slightly greater, if any, due to the fact that the consumer will have more reason for seeing that his household appliances are adjusted to give the highest degree of efficiency. As to the large users of gas, I doubt if the artificial gas substituted for the natural gas will cost over four or five cents more per

1,000,000 B.t.u. than it now costs them. In fact, due to the recent developments in the complete gasification of low-grade coals, plants are on the market to-day which will produce a very high-grade gaseous fuel (superior to the ordinary producer gas) which can be sold for less than 50 cents per 1,000,000 B.t.u. What we as engineers need to consider most is the efficient utilization of the fuel we have, whether it is coal, coke, oil or gas, and in this way overcome the increasing cost of the fuel we use. Furthermore, we should learn to select our fuel, not from the standpoint of cost per 1,000,000 B.t.u. but from the standpoint of the ultimate cost of the finished product. When we do this we will find that in the majority of cases a gaseous fuel, even though more expensive on the B.t.u. basis, will be cheaper in the long run.

MR. THOMSON KING:* Two of the former speakers have interested me very much by the comparison of gas and oil. I had the same experience with end heating furnaces with artificial gas in the Baltimore & Ohio shops in Baltimore. We took a furnace operating on oil and operated it for a week, keeping a very careful record. We relined the same furnace, doing nothing except to reduce the combustion chamber, and put in a good gas burner with proper arrangements for the correct proportioning of air and gas. We ran it a week on gas with the same operator, the same work and the same relative conditions, and with that crude furnace we made 1000 cubic feet of 550-B.t.u. gas do the work of five gallons of fuel oil. With this artificial gas, the cost of oil would have been greater than the cost of gas, of course; but we had less scaling, better working conditions, better control of our heat, and less wear and tear on the furnace lining. If we were working with natural gas of just about twice the heat value, we would put 1000 cubic feet of natural gas against 10 gallons of oil—and remember, these tests were not in a furnace designed for gas, but in a crude oil furnace rebuilt as a gas furnace. We could have gotten better results if we had made our comparison with a furnace designed to burn fuel gas. I believe that in practically any operation, excepting maybe a few which are exceptions to the rule,

*Sales Manager, Gas Boiler Department, Peerless Heater Co., Pittsburgh.

with the gas you have in Pittsburgh you can beat oil at any prices that we are likely to have in the next 10 years.

There is one feature of this subject which is probably the most important of all and which should be considered in this discussion. This feature of surpassing importance is that gas is absolutely destined to be the fuel of the future. Our modern civilization and modern industry will not continue to tolerate the burning of raw fuels such as coal and oil. Neither of these is in the proper shape for controlled combustion and, while oil has many fine qualities to recommend it as an industrial fuel, it will become increasingly valuable for other uses, particularly as a fuel for marine work, for which it is peculiarly adapted.

We are going to need and find more and more gas. When we cannot get a sufficiency of natural gas it will be supplemented by manufactured products. Probably the development will be along the lines of the locating of very large plants for the complete gasification of coal at the mines and in the coal regions and the transmission of gas to our cities.

These plants will give us gas for heating, coke when desired for metallurgical purposes, ammonia for fertilizer, benzol and toluol for gasoline substitutes, and coal-tars for the immense variety of uses to which they can be applied. We cannot afford to haul low-grade coal by freight to our cities, burn it inefficiently and recover, as by-products, nothing except smoke and dirt.

In the next 20 years we are going to see almost a revolution by which gas will take over practically all industrial heating processes except the very high-temperature processes such as steel making and a few other specialized conditions, and the sooner we arrive at this result the better it will be for all concerned.

Mr. Morris Knowles, *Chairman*:* In that Baltimore & Ohio experiment was by-product gas used?

Mr. Thomson King: Mixed coke-oven gas and carbureted water-gas, running about 550 B.t.u.

Mr. A. E. Anderson:† This discussion of natural gas leads

*President, Morris Knowles, Inc., Pittsburgh.
†Attorney, Pittsburgh.

me to take the opportunity, in spite of the retort courteous from the Chairman, to add a little history. These fuel engineers speaking of the use of gas by the spoonful carries my mind back to the original well, which was used first for industrial purposes, which was drilled within a mile and a half of my home, near the village of Lardentown, back in 1877, and that well was first used by the Spang, Chalfant mill in Etna. As a comparison of what is done with gas wells to-day, that well blew off with such force (they did not have rock pressure and they did not know how to shut off a well in those days) that it did not begin to ignite for at least five feet from the end of a six-inch casing, and that blew against the hillside for at least two years––all the time they were building that pipe-line about 18 miles. If that well had been on a hilltop, instead of in a valley, we could have read a paper at our house at any time of the night. When they completed that pipe-line they wanted to make a test to find out whether it was clear; so, before they turned in the gas, they put in a rubber ball less than the diameter of the pipe and it went about ten miles and was lost. They had quite a time locating that obstruction. When they did locate it they unjointed the pipe and found that someone had put a rail in there and that stopped the ball. When they took that out and put in the ball again it made the 18 miles in 22 minutes. So that when that gas was used in the Spang, Chalfant mill that was the first use of natural gas for industrial purposes and was the pioneer use of gas which has developed to the extent we have heard stated here to-night.

The question I had in mind to ask is this. A gentleman over here used the term "ideal fuel." My first question is how nearly manufactured gas will approach the ideal fuel; and, following that, these other substitutes for natural gas. Is there a schedule of comparison, taking natural gas as the standard, showing how nearly these other fuels will approach, in use and convenience and otherwise, what natural gas has been and we hope will be?

Mr. A. E. Blake: There have been two or three remarks since I sat down that I may be able to amplify. Mr. Moyer called attention to the decline of the natural-gas supply. It may be of interest to add that some of the local gas people have noticed,

through careful observation of records, that natural gas is also becoming richer.

The following, from a lecture by Dr. J. B. Garner, August 23, 1922, before the Natural Gas Association of West Virginia, Clarksburg, W. Va., will be found of much interest:

"Numerous tests at regular intervals have been made of the composition, heating value, specific gravity, and gasoline content of the natural gas of West Virginia during the past four (4) years. These tests have been made on samples of gas secured at the large Metering Stations, and at the Gasoline Plants. As a result of these tests it has been shown conclusively:

1st—That the content of Methane in natural gas is becoming less and content of the other hydrocarbons is becoming greater;

2nd—That the heating value of natural gas is increasing. At one station since March, 1919, the heating value has increased from 1,163 to 1,248 B.t.u. (December, 1921);

3rd—That the specific gravity is increasing (0.6357 in March, 1919, to 0.6832 in December, 1921); and

4th—That the gasoline content is increasing—370 gallons per million in 1919, to 463 gallons per million in 1921.

Further changes in composition and other qualities are certain to occur as the rock pressures in the Fields decline."

Another thing brought out by Mr. Moyer is the interest to be found in the study of mixtures of manufactured gas with natural gas. Take 1126-B.t.u. natural gas, 60 per cent., and 300-B.t.u. blue water-gas, 40 per cent., and you may be surprised to know that the mixture will be 796 B.t.u. Such gas can be used practically without change of present equipment. No town in manufactured-gas territory is ever likely to have gas of such grade as that, even for the ruling prices, which are generally from 65 cents to $1.75 per 1000 cubic feet (for industrial use) for gas having from 500 to 600 B.t.u.

Speaking again of theoretical flame or reaction temperature, Mr. Henry was very timely in his remark in which he called attention to the very active dissociation at higher temperatures of carbon dioxid and water vapor. We might as well recall the principal assumptions to be made in calculating this theoretical value; namely, (1), that the combustion (chemical reaction) is quantitative, without excess of air or fuel being present; (2) that there is no loss in the gross energy developed, by radiation, ionization, dissociation, or intermediate chemical reactions of gases present; (3) that the gross energy resulting from perfect combustion of the homogeneous mixture of air and fuel in quantitative reacting proportions, minus the latent heat of steam, due to the presence of

any hydrogen in the fuel, and minus the heat necessary to raise it to the temperature of vaporization and the latent heat of vaporization of the fuel if it is not already gaseous, manifests itself as heat in the resultant products. The temperature which these products would have under these conditions is the figure properly sought, and one which has considerable virtue in comparing fuels of various grades, as stated before.

Mr. F. K. Howell:* Mr. King brought up a very interesting point which might bear some discussion. He stated that the fuel of the future would be gas, and artificial gas eventually, with the thought that the production of that artificial gas should be close to the point of mining the coal. It seems to me that when all the factors which enter into the location of an artificial-gas plant are considered—freight rates on coal (even of considerably less B.t.u. value than that at present gasified), freight on by-products, transportation, cost of gas fuel, etc.—it will be found in the future, as in the past, that the artificial-gas plant will be built close to the point of use of the by-products and the gas. I do not believe you gentlemen realize the extremely large investment that is required to transport gas a long distance. If we attempt to go to the coal-mines we would be simply duplicating that big investment which has been necessary to get the natural gas from the wells to the cities. Fixed charges on that sort of investment are very great and have to be considered in any selection of site for an artificial-gas plant.

Mr. E. D. Leland:† The possible efficiencies in the use of natural gas is certainly a very important topic for discussion in the Pittsburgh district, because we have become so accustomed to using large volumes of natural gas with high heat values that we have not paid the proper attention to, or laid sufficient emphasis on, getting all the benefit of these heat units. It is well known that the amount of natural gas available for Pittsburgh has been growing less for quite a number of years, and it is very encouraging to the engineers of this district to have a man like Mr.

*Superintendent Compressing Stations, Equitable Gas Co., Pittsburgh.
†General Manager, Equitable Gas Co., Pittsburgh.

Henry come here and explain some of the excellent results obtained by means of proper appliances in connection with the consumption of manufactured gas. While it will probably be quite a number of years before Pittsburgh is entirely dependent upon manufactured gas, still it is well that our Society is starting early to discuss these matters; for it is upon the engineers of the Pittsburgh district that proper results in handling the gas of the future must rest.

I might say a word about the effect of price upon the use of gas. Over thirty years ago, in the days of the great Indiana gas field, one could get gas enough to run a cook stove an entire month for 25 cents, and there was slight attention paid to efficiency in the use of the gas. Excessive amounts were used and more or less wasted. The drain upon the field soon reduced the rock pressure and made the production of gas more costly. The increased rates that were thus made necessary brought about such efficient use of the more costly fuel that in 1921, according to a recent government publication, the maximum price per 1000 cubic feet paid in Indiana for natural gas was $1.29. The point is that they would not have used natural gas at $1.29 unless they found they were getting their money's worth out of it. Evidently the higher rates were largely neutralized by the efficiency in the use of the gas.

Mr. Morris Knowles: Mr. Stephany, you said that the price of gas did not depend upon the B.t.u., but upon other things. Will you amplify the statement in your discussion?

Mr. C. F. Freeman:* Mr. Stephany's paper sounds another warning to the users, both domestic and industrial, of natural gas in the Pittsburgh district that the time has come when more care and greater engineering skill should be employed in its proper utilization.

The Pittsburgh district was the first section of our great country to be blessed with, and to profit by, Nature's gaseous fuel; and how recklessly we went about wasting it is denoted by the present-day depletion of our gas wells. The Southwest is at the same stage that we experienced twenty-five years ago—frightful

*District Manager, Surface Combustion Co., Pittsburgh.

waste of natural gas, with no thought for the future—and it is to be hoped that other sections of the country located near the newer gas fields will take heed of the lesson to be learned from the present-day Pittsburgh district.

I believe all of you will agree that the supply of natural gas has been an important factor leading to the present-day development of industrial Pittsburgh. If we are to retain our standing as an industrial center, it behooves all the manufacturers of this district to pay strict attention to the methods employed in their plants in the combustion of natural gas for all heating operations. This applies also to the domestic consumers, and especially to those who have been using gas for heating their homes. The "send out" or daily load which any gas company must carry on its lines is in very few instances determined by the industrial users. By that, I mean that the peak-load of any gas company comes at the times during the cold spells when the great number of domestic users start up their heating furnaces burning natural gas. The industrial load is practically constant throughout the year, with the exception of fluctuations due to business conditions, when the gas company's "send out" will vary with the rise and fall of the industries particularly involved. As Mr. Stephany has so aptly put it, the natural-gas companies in this district have followed the rule of the sea, "women and children first," which simply means that the domestic consumers must be taken care of prior to the industrial plants. If more attention were given by the householder to the proper utilization of natural gas in his home, the sad experience of many of the industries which are cut off from the supply during the winter cold spells would be lessened to a great degree. The average individual, as a general rule, never stops to consider that when he is burning natural gas by means of some obsolete or dilapidated gas burner in a house heater primarily designed for soft-coal firing, he seldom gets over 30 per cent. heating efficiency from his equipment. In the proper type of heater, designed for natural-gas firing, 60 per cent. efficiency would be the rule rather than the exception.

Many of the natural-gas consumers in this district would do well to take a lesson in economic gas utilization from those consumers in other cities where artificial gas is supplied. Compared with artificial gas at $1 per thousand cubic feet, which is the preva-

lent price in other cities (the gas having a B.t.u. value of 580), natural gas of 1000 B.t.u. per cubic foot in this district, on an equal B.t.u. basis would be worth approximately $1.75 per thousand cubic feet. The thought, in itself, of such a price for natural gas should be sufficient for all of us in this district to pay stricter attention to conservative use of our present-day supply. I do not want you to infer by any means that the price of natural gas is ever going to reach such a high level of price; for, long before that time comes, artificial gas will have found its way into the Pittsburgh district.

The salvation of the natural-gas supply in the Pittsburgh district is one of price plus efficient utilization, dependent upon the supply available and the service rendered for that price. Gas rates should be charged and based on the principle of book cost to keep a consumer on the lines. On this basis, the domestic users would pay a much higher rate than the industrials, who in turn would pay according to the amount used and the seasonable supply available.

It is a well-known fact with all gas companies, whether supplying artificial or natural gas, that the unit cost of carrying a domestic account on their books is considerably higher than that of an industrial user, and yet in Pittsburgh the domestic consumer pays no higher price per thousand cubic feet, and has also the privilege of first call on the supply during periods of greatest demand. The cost of running a large gas service into a manufacturing plant, plus meters, upkeep, distribution expense, overhead, accounting charges, and sales expense included, is considerably less per thousand cubic feet handled than the same cost per thousand cubic feet handled through a domestic service line. On this basis, which is the only equitable one, it is only fair that the domestic consumer should pay a higher price for gas than the industrial user. To-day the industrial patrons carry part of the price load rightly chargeable to the domestic users, while from the service standpoint they receive only secondary consideration.

The industrial user has also taken the lead in promulgating better and more up-to-date methods for burning the gas. Where we formerly found ordinary pipe nipples or raw-gas burners in furnaces which could be considered only as a crude pile of bricks,

we now see modern furnaces designed on sound combustion principles. These up-to-date furnaces are usually equipped with burners and mixers which produce the best combustion efficiency possible for the particular heating operation in hand. Of course, there are numerous makeshift changes to obtain better furnace efficiencies—such as existing furnaces equipped with modern burners and mixers; new furnaces of good or poor design, perhaps with efficient or inefficient burners, as the case may be; so-called "three-in-one" furnaces, where the furnace might be proper for a particular heating operation, but, much to the owner's chagrin, will not perform all of his varied heating operations with equally good results. Any of these attempts produces results commensurate with the degree of knowledge of furnace and combustion efficiency displayed by the parties making the changes or installations.

Mr. Stephany has cited a few cases of several Pittsburgh industries where better and more efficient results have been obtained with natural gas by applying up-to-date principles in its use. It is well to note that in the majority of cases he cites the results were accomplished upon existing furnaces with slight changes in furnace design, but always a change or improvement in the method of mixing the gas and air and feeding it to the furnace. This, in itself, is proof that it is not always necessary to install entirely new furnaces, providing the furnace is adapted to the work in hand and designed primarily for natural gas. I believe it is also well to point out that none of the figures mentioned in the comparisons between the old and new results is to be taken as the best or highest efficiency that could be obtained for the particular class of work mentioned. For instance, all brass melting is not alike; rod and bar heating, carbonizing, etc., are not always the same in all plants.

Some of these installations may have been makeshifts—the best at hand at the time—but, even so, the comparative results prove what can be done if an attempt at better utilization is made. The attempt, however poor, usually produces some results and is better than no attempt at all, for it has at least awakened the natural-gas user to the realization that the time has come to begin a program of natural-gas conservation by means of more efficient utilization, whether through his own organization or by assistance

from outside established combustion engineers. After all, gas engineering, like all engineering, is sound common-sense plus a little simple mathematics.

Mr. E. J. Stephany: Practically all the points of which I had taken note have been answered. I would like to say in defense of the figures I have used that I did not try to show the best operating results that had been obtained in each particular operation. I did not try to cite the *lowest* gas consumption recorded. For instance, I showed a case where the consumption per 100 pounds of brass had been reduced from 325 to 275 cubic feet. I have been informed by one manufacturer that he is willing to guarantee to melt brass with 2000 B.t.u. per pound, which would be less than 200 cubic feet of natural gas per 100 pounds of brass.

Mr. Freeman's remarks and Mr. King's regarding natural gas are very interesting to me, because I am not primarily a natural-gas man. My training was with manufactured gas, where we sold manufactured gas at 90 cents in competition with cheap coal and cheap oil. In Chicago, where the gas rate is $1.15 to 80 cents for a gas of about 565 B.t.u., they keep over fifty industrial engineers busy, and are selling about 25 per cent. of their output for industrial purposes.

Mr. Mueller asked three questions. Regarding the mixing of coke-oven gas with natural gas I know of only one place where that is being done, and that is Buffalo. Buffalo is now supplying a mixture of coke-oven gas and natural gas, and I believe their B.t.u. per cubic foot is about 980.

Regarding the formula used for measuring flow through pipe, we do use Pole's formula; but instead of figuring a long formula every time, we use a little chart which figures it out in about three seconds.

I do not have here the exact figures regarding recuperation, but I have figures at the office and I will supply them to Mr. Mueller if he desires.

It would be rather difficult to prepare a chart showing the relationship between fuels with natural gas as 100 per cent. There are certain operations where other fuels are better than natural gas. In welding steel tanks, at least two manufacturers in this district are using blue water-gas because of the higher tempera-

tures obtained. In order to compare fuels you have to compare them for a certain particular operation. However, I believe that, with few exceptions, natural gas will rank at the top as an industrial fuel in Pittsburgh.

Mr. Anderson is evidently interested in a comparison of the B.t.u. value of different fuels. I have usually used the following:

Natural gas, 1100 B.t.u. per cubic foot.
Coke-oven gas, 540 B.t.u. per cubic foot.
Carbureted water-gas, 500 to 600 B.t.u. per cubic foot.
Blue water-gas, 300 to 325 B.t.u. per cubic foot.
Producer gas, 100 to 160 B.t.u. per cubic foot.
Fuel oil, 140,000 B.t.u. per gallon.
Coal, 13,500 B.t.u. per pound.

Regarding my statement that the value of a fuel is not dependent upon its B.t.u. content and price alone, I might state that there is such a thing as form value. That has been referred to. Take a liquid fuel which must be gasified before it is burned. There are certain costs attendant—pumping the oil, supplying the air, the steam to heat it, and the energy absorbed in gasifying the oil.

A greater excess of air is necessary than for gaseous fuel, and in the case of oil and coal it is always necessary to have excess air. There are quite a few other factors which must be considered, such as the possibility of applying the fuel in a particular case. Take a seven-story loft building. It will be necessary to haul the coal up an elevator, dump it on the floor, shovel it into the furnace, haul the ashes away, etc. A gas fuel at many times the cost would be a better fuel than a solid fuel in such a case.

I feel very grateful to those who have taken part in this discussion and added such valuable information on the subject.

THE PROBLEM OF CORROSION IN THE COAL-MINING INDUSTRY*

By George M. Enos†

INTRODUCTION

The failure of materials through corrosion processes is an important problem in nearly all branches of engineering construction. Competent authorities have estimated the annual cost of the wastage due to the rusting of iron and steel throughout the world as amounting to many hundreds of millions of dollars. Adding to this cost the amount lost by the corrosion of the non-ferrous metals and alloys, it can readily be seen that the problem is a very serious one.

In the coal-mining industry, losses due to corrosion occur in both surface and underground equipment. Corrosion of the surface equipment by the atmosphere and other gases need not be discussed here, and it is probable that such loss is very small in comparison with the losses due to the corrosion of mining equipment by acid mine water. The failures of pumps and pump parts, track, pipe-lines and other equipment resulting from the action of acid mine water cause considerable financial losses to mine operators. The losses are due not only to the actual cost of the materials, but also in many cases to the labor cost, and the loss resulting from the enforced shut-down of a part of the mine which sometimes results from the failure of pumps or pipe-lines through corrosion by the acid mine water.

During the past three years, the United States Bureau of Mines, in co-operation with the Carnegie Institute of Technology and the coal-mining industry, has been studying the problem, and several investigations have been completed, while several are still in progress. It is the purpose of this paper to point out some of the results of these investigations; and, in particular, some of the field observations which have not been noted in the joint publications[15, 16, 19]‡ dealing with field and laboratory tests. Before dis-

*Published by permission of the Director, U. S. Bureau of Mines, Department of the Interior.

†Junior Metallurgist, Non-Ferrous Metals Section, Pittsburgh Experiment Station, U. S. Bureau of Mines.

‡See bibliography at end of paper.

cussing the practical side of the subject, it is in order to discuss briefly, (1) the nature of corrosion in general; (2) the nature of acid mine water; (3) the nature of the failure of engineering materials in acid mine water; and (4) factors which influence the rate of failure.

The Nature of Corrosion. In the broadest sense corrosion may be defined as that process which results when a metal is exposed to a condition which will cause it to revert to a state of more chemically stable equilibrium. This is accomplished by the interaction of the metal with a corroding medium, which may be a gas, a liquid, or a combination of gas and liquid. This reaction is the oxidation of the metal or alloy. The products of such a reaction are salts, hydroxids, or oxids of the metal corroded. Many theories have been advanced to explain the mechanism of corrosion. It is beyond the scope of this paper to discuss the merits of the various theories. In a recent investigation, R. J. Anderson and the author have studied this phase of the corrosion problem in considerable detail, and the results will be published shortly. Corrosion is evidenced by the formation of decomposition products such as coatings or precipitates, by a gradual wearing away of the surface, by the formation of pits, or by any or all of these in combination. Other corrosion phenomena are sometimes noted, such as embrittlement, and redeposition of one of the constituents as metal on the corroded piece, but these are less common occurrences.

The Nature of Acid Water from Coal-Mines. The composition[14] of mine waters varies, of course, according to the locality of the mine. The water from any particular mine will vary according to the season of the year, the age of the mine and other factors. Water which has been allowed to flow through old workings is usually more acid than water from a new opening.

The acidity of mine water is due to the presence of free sulphuric acid. The mine water will also usually contain considerable amounts of sulphates of iron and aluminum, and smaller amounts of sulphates of calcium, magnesium, sodium and potassium. Silica and chlorids are usually present. In some mines the chlorid content of the mine water is sufficiently high to be a serious factor. In Table I are given figures showing the range in composition for acid water from bituminous coal-mines.

TABLE I. VARIATION IN THE COMPOSITION OF TYPICAL MINE WATER FROM COAL-MINES IN PARTS PER MILLION*

Constituent	*Low value*	*High value*
SiO_2	16	160
Fe^{++}	trace	1216
Fe^{+++}	11	1303
Al	trace	1434
Ca	79	436
Mg	9	197
K	0	373
Na	21	2286
Cl	0	625
SO_4	790	12115
Suspended matter (on unfiltered water) dried at 150 degrees C.	6	91
Acidity due to free sulphuric acid	trace	3662
Acidity due to free sulphuric acid plus sulphates of iron and aluminum	2180	17200

The free sulphuric acid and the iron sulphates result from the oxidation by air and solution by water of the pyrite and marcasite associated with the coal. The equations expressing this reaction are:

$$2\ FeS_2 + 7O_2 + 2H_2O = 2\ FeSO_4 + 2H_2SO_4$$
$$4\ FeSO_4 + 2H_2SO_4 + O_2 = 2Fe_2\ (SO_4)_3 + 2H_2O.$$

Nature of Failure of Metals and Alloys in Acid Mine Water. A common way in which metals fail in mine waters is by a uniform wearing away of the surface. An example of this kind of corrosion is given in Fig. 1, which shows a test-piece of rolled "Monel" metal after corrosion. Another common method of failure is by pitting. In Fig. 2 is shown a cast aluminum alloy which failed in this manner. Embrittlement is sometimes caused, and the remains of a corroded test-piece of naval brass which failed in this manner are shown in Fig. 3. Other photographs of corroded materials

*To convert parts per million to grains per U. S. gallon, multiply by 0.0583.

Fig. 1. Rolled "Monel" Metal.
(Composition, Ni, 65.1; Cu, 30.52; Fe, 4.2. Coating easily removable. Uniform corrosion. Days immersed, 79. Loss in milligrams per square centimeter per day, 6.79.)

Fig. 2. Cast Aluminum-Manganese Alloy.
(Approximate composition, Al, 98; Mn, 2. No coating. Irregular pitting. Days immersed, 72. Loss in milligrams per square centimeter per day, 2.23.)

Fig. 3. Rolled Naval Brass.
(Approximate composition, Cu, 60.4; Zn, 38.8; Sn, 0.08. Coating removable with difficulty; pieces brittle and easily broken. Days immersed, 65. Loss in milligrams per square centimeter per day, 7.86.)

Fig. 4. Rolled Ingot Iron.
(Composition, Fe, 99.9. Coating removable with difficulty. Considerable uniform corrosion, with tendency to pit. Days immersed, 35. Loss in milligrams per square centimeter per day, 6.89.)

Fig. 5. Rolled Nickel Silver.
(Approximate composition, Cu, 66.0; Zn, 24; Ni, 10; Fe, trace. Coating easily removable. Considerable uniform corrosion. Days immersed, 65. Loss in milligrams per square centimeter per day, 7.84.)

Fig. 6. Rolled Alloy Steel.
(Composition, Ni, 29.60; Si, 3.26; Cr, 10.73; C, low; Fe, remainder. No coating. No visible corrosion. Days immersed, 135. Loss in milligrams per square centimeter per day, 0.00089.)

are shown in Fig. 4-6. Fig. 4 shows the condition of commercially pure iron after corrosion. Fig. 5 shows a badly corroded piece of nickel silver, and Fig. 6 is a view of a rustless steel which had corroded only a very small amount.

Sometimes one constituent is redeposited after solution, as in the case of the corrosion of low brass in the Montour No. 1 mine. Copper was deposited from solution after corrosion, as illustrated in Fig. 7. Coatings of various kinds may be formed on materials. A hard impervious coating formed on a hard-rolled phosphor bronze is shown in Fig. 8. In the case of some brasses, copper is redeposited very evenly, as in the case of a manganese brass shown in Fig. 9. In Fig. 10 is shown the typical structure of the deposited material on a cast manganese-brass alloy.

With the exception of the piece shown in Fig. 7, the pieces shown were all corroded in the Edna No. 2 mine water during the investigation reported in Bulletins 4 and 5[15, 16]. The piece shown in Fig. 7 was corroded in the Montour No. 1 mine during the same investigation. The text accompanying the figures makes them self-explanatory.*

Factors Influencing Corrosion in Acid Mine Water. Detailed discussion of the various factors affecting corrosion in acid mine water need not be given here, and it is sufficient to list the possible factors with a brief comment on their relative importance. The factors are:

1. Chemical composition of the metal or alloy.
2. Physical condition of the metal or alloy.
3. Chemical composition and concentration of the mine water.
4. Velocity of flow.
5. Temperature of the medium.
6. Time period of exposure.
7. Solution pressure of the metal or alloy which depends on 1, 2 and 3.
8. Electrical conditions of immersion.
9. Effect of light.

*In the lecture many more pictures of corroded metals and alloys were shown, but space permits publishing only a few typical examples.

Fig. 7. Copper Deposited from Mine Water on Corroded Edge.
(Low brass, 80:20 Cu-Zn. Test-piece corroded 57 days in acid mine water, Montour No. 1 mine. Etched with $NH_4OH + H_2O_2$. $\times$ 100.)

Fig. 8. Coating on Edge of Hard-Rolled Phosphor Bronze.
(90:4.5:5.4:0.1 Cu-Pb-Sn-P; 135 days in Edna No. 2 mine water. Etched with $NH_4OH + H_2O_2$ and $FeCl_3$. $\times$200.)

Fig. 9. Cross-Section of Cast Manganese Brass.
(68:28:2:2 Cu-Zn-Fe-Mn. Test-piece corroded in Edna No. 2 mine water 72 days. Not etched. Oblique illumination, $\times$2.)

All of these factors, and perhaps others, are important, although for most cases factors 5, 8 and 9 can be neglected, at least in mine water. All of these factors will be discussed at length in a forthcoming publication. It will be well to note briefly some of the effects of the more important factors on corrosion rate.

In testing metals and alloys for corrosion rates or comparative relative corrosion losses the object is to vary but one factor at a time, maintaining all others as nearly constant as is practicable. By varying each of the important factors in turn, its relative

Fig. 10. Grain Boundary Outline in Corroded (Deposited Copper) Material of a Cast Manganese-Brass Alloy.
(67:30:2:1 Cu-Zn-Mn-Fe; 72 days in Edna No. 2 mine water. Structure shown is in deposited layer on test-piece. Etched with $NH_4OH + H_2O_2$ and acidic $FeCl_3$. $\times 300$.)

importance can be determined. It is obvious that the chemical composition is the most important factor, and it should be noted that in previous investigations[15, 16] it is the effect of variation in chemical composition which has been most studied, while the other factors have been maintained constant. A brief discussion of the various factors follows:

1. It can be assumed that the chemical composition of any given alloy can be duplicated closely enough for practical purposes; thus in testing alloys the chemical composition can be made a constant or variable as desired.

2. By suitable methods of working, physical properties such as hardness, grain size, tensile strength and other physical properties can be closely duplicated, and so varied or made constant.

3. Mine water is a solution the chemical composition of which varies almost from minute to minute, and the day-to-day and seasonal variations may fluctuate between wide limits. Since in laboratory tests it would be impractical to duplicate this variation, it is preferable to test in actual flowing mine water, although it is probable that comparable results will be obtained in laboratory tests if mine water of composition the same as the average for a long period of time be used.

The physical constitution of the solution; that is, the amount of sediment carried, and the amount of colloidal material not included in the chemical composition—e. g., the residue from filtration before analysis—will also vary and cannot be easily duplicated.

4. The velocity of the water, or (the same thing) the rate of the movement of the material in the water, is undoubtedly an important factor. It is probable that the corrosion rate increases with increasing velocity up to a certain limiting value.

5. It may be assumed that the temperature of the mine water will not vary enough in actual practice to affect the corrosion rate.

6. The time period of exposure is usually a fixed factor; e. g., exposure is made for a given length of time in testing materials, or, if the test be in the nature of a practical field test, the corrosion may be allowed to proceed to failure and the time period noted. In practice, the object is to make the time period as long as possible.

7. The solution pressure of the metal or alloy is a factor which depends on factors 1, 2 and 3 mentioned above, and is a partial measure of the tendency of the metal to corrode.

8. The electrical conditions of immersion are usually carefully controlled. Stray ground currents may cause electrolysis, but for testing, at least, the factor may be regulated so as to have no effect.

9. The effect of light upon the corrosion rate is probably very small and can be neglected for most purposes.

TESTING METHODS USED BY THE BUREAU OF MINES

In order to ascertain what metals or alloys are best suited to withstand the corrosive action of acid mine water, several investigations have been carried out. W. A. Selvig, assistant chemist of

the Bureau of Mines[13], made tests for the American Society for Testing Materials on a number of commercial grades of iron and steel in acid mine water. Later W. A. Selvig and the author[14] made extensive tests on a group of 45 metals and alloys in waters from three coal mines of the Western Pennsylvania coal region. This was followed by work by R. J. Anderson and the author[15] on the microscopy of the materials corroded in the previous test. The results of the last two investigations showed that there were five alloys which showed considerable resistance to the action of the acid mine water; namely, a high-chromium steel, two high-chromium-nickel-silicon steels, a high-silicon cast-iron, and a nickel-chromium-iron alloy. R. J. Anderson, J. R. Adams and the author have since studied the fundamentals of corrosion and methods of accelerated testing, particularly in connection with corrosion in acid mine waters, and the results of this investigation will be published shortly.

In making tests for the American Society for Testing Materials[13], Selvig used test-pieces of iron and steel which were of rolled stock, 16 and 22 gage. These pieces were cut to two by six inches, and after measuring and weighing were immersed in racks in flowing mine water at the Calumet mine of the H. C. Frick Coke Company. After corrosion for a number of weeks the pieces were removed, cleaned, dried and weighed and the loss in weight noted. The results were not encouraging from the viewpoint of their use in mine water, and none of the materials showed marked resistance to the attack of the acid water.

In tests made by W. A. Selvig and the author both ferrous and non-ferrous metals and alloys were tested. The rolled pieces were 16 gage by two by six inches and the cast pieces were one-fourth by two by six inches. The pieces were immersed in flowing mine water at three mines in the Western Pennsylvania coal region; namely, Montour No. 1 mine of the Pittsburgh Coal Company at Southview, Washington County; Edna No. 2 mine of the Hillman Coal and Coke Company at Wendel, Westmoreland County; and Calumet mine of the H. C. Frick Coke Company at Calumet, Westmoreland County. The test boxes used were of improved design. The flow of water was carefully regulated.

In both the preceding tests the test-piece was considered to have failed if it corroded through, or if the edge had corroded to

a depth of one-fourth inch or more. The results of these tests have been noted in preceding paragraphs.

The long-time immersion tests were satisfactory in that they gave comparable results under conditions approximating practice; however, they had the disadvantage of taking several months for completion. Moreover, they are purely empirical and, while of considerable value for comparative purposes, do not throw a great deal of light on the fundamental causes. It was therefore decided to study fundamentals of corrosion, and also to develop an accelerated test for comparative testing.

The results of this investigation are of considerable interest, but only a summary of the method of accelerated electrolytic testing will be given, as the other results are not in form to discuss at this time.

Preliminary investigation showed that it was practicable to use an electrolytic test for obtaining quick, comparative corrosion losses. Later, extensive tests made on metals and alloys previously corroded in the long-time tests showed that the results obtained in the electrolytic accelerated test are directly comparable with the results from the long-time immersion tests.

The accelerated electrolytic test is carried out as follows: A test-piece of the material is prepared, of such shape that a measured area can be exposed to the electrolyte. Either cylindrical or flat test-pieces are suitable, and the total surface area is usually from 20 to 30 square centimeters, and the area submerged about 14 square centimeters. A copper wire is soldered to the piece, and the piece is attached by the wire to the rotating anode on an electrolytic machine. The machine is of the type used in electrolytic analysis. Speed control of the rotating anode is essential, and it is also necessary to regulate the amperage closely, which is done by means of a lamp bank resistor. It was found that approximately the following conditions gave the best results: speed of rotation of anode, 140 r.p.m.; area of test-piece submerged, 14 square centimeters; current imposed, 0.025 ampere; current density, 0.179 ampere per square decimeter.

Heavy-walled glass beakers of about 500 cubic centimeters capacity are used to hold the electrolyte. The run is continued until a weighable loss is obtained, and usually a time period of six or eight hours is sufficient. The test-pieces are weighed and meas-

ured prior to immersion and cleaned, dried and weighed after immersion and the losses in weight noted.

In Fig. 11 is shown a typical test-piece after corrosion in the

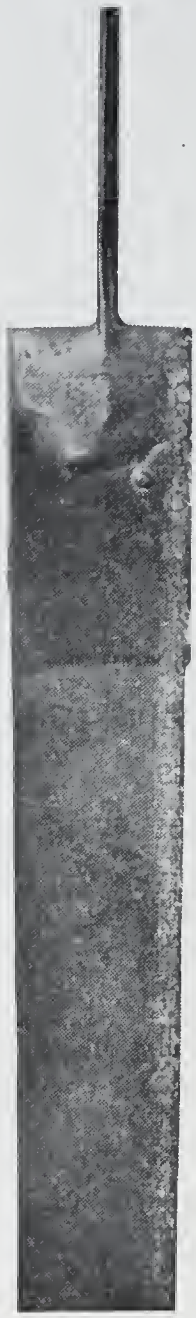

Fig. 11. Test-Piece of Rolled Naval Brass.
(60:39:1 Cu-Zn-Sn, after corrosion in Edna No. 2 mine water. Note wire for attaching to rotating anode.)

accelerated electrolytic test. Fig. 12 is a view of the apparatus used in testing as developed at the Bureau of Mines.

In Fig. 13 are plotted the losses in the long-time immersion test and also the losses obtained in the accelerated electrolytic test. An examination of these graphs shows that the accelerated test has increased the corrosion rate from 10 to 12 times, and it is found that the corrosion characteristics such as pitting, coatings formed,

etc., are identical in both tests. In this short paper it is not possible to give a complete discussion of all the data or of all the phenomena observed. It should be noted that an exact conversion factor from accelerated electrolytic tests results to long-time immersion tests results is probably not obtainable; however, tests made by the accelerated electrolytic test are comparable among themselves, and the relative order of corrodibility of various metals and alloys is obtained.

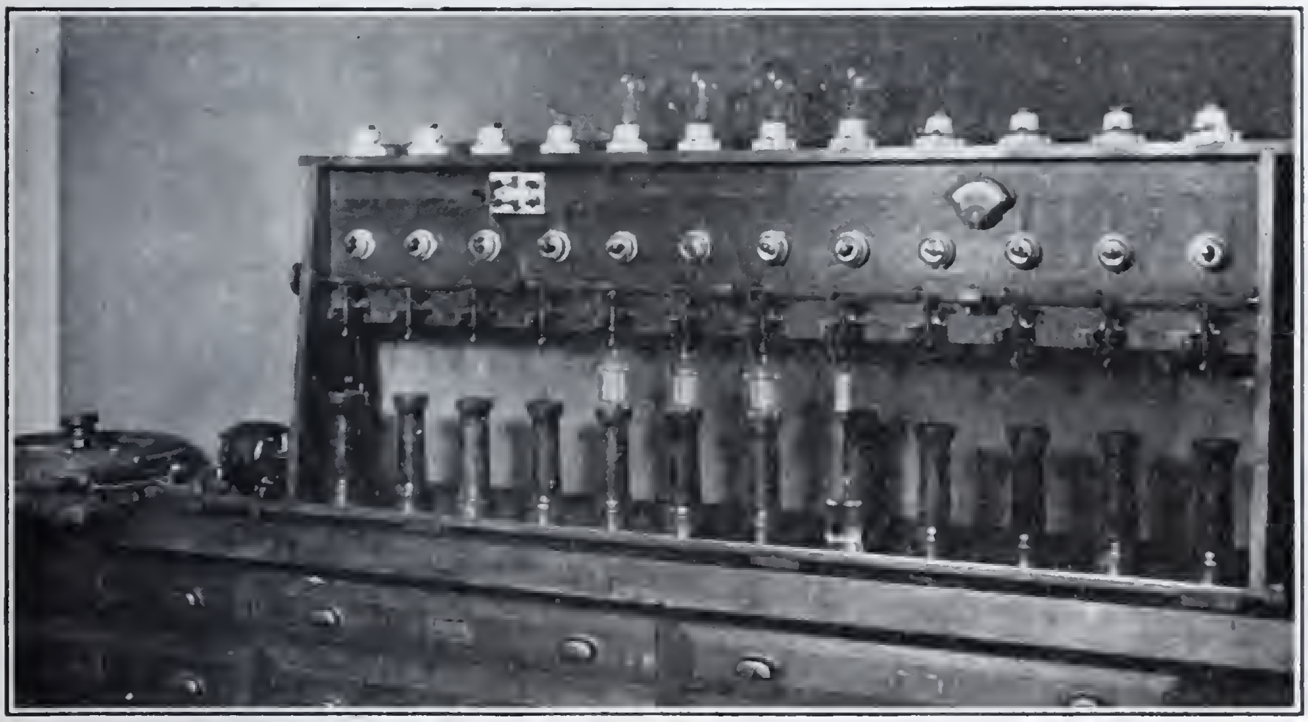

Fig. 12. Apparatus Used in Making Accelerated Electrolytic Tests.

It should be noted also that this test is applicable to cases of corrosion in solutions other than mine water, although all of the correlation so far has been with long-time data obtained in mine-water tests.

In the preceding paragraphs the author has reviewed briefly the various factors in corrosion processes and outlined the methods of testing employed by the Bureau of Mines in studying mine-water corrosion. In the second part of the paper some of the practical difficulties encountered because of the corrosion of mining equipment will be considered and suggestions offered for combating corrosion losses.

CORROSION PROBLEMS OF THE COAL-MINE OPERATOR

Probably the most important problem is that of the corrosion of pumping equipment. Pumps which may give excellent service under ordinary conditions, where the mechanical strength, workability and other physical properties are the only factors to be considered, may not resist the action of acid mine water. Brass and bronze, as well as ordinary cast-iron and ordinary steel, corrode rapidly in acid mine water. In many mines it has been the practice to babbitt the pump chambers. This will partially solve the problem, but is not entirely satisfactory for mechanical reasons. Lead-lined chambers give good service, if the lining is tight against the outer wall and does not permit leaks. Porcelain plungers are giving good service, and, if properly cared for, may be safely substituted for the brass and bronze or cast-iron plungers used. One advantage in the use of porcelain plungers is that packing troubles can be reduced if this type of plunger is placed in the pumps true and level. If there is any appreciable give or flexure after mounting, the porcelain may crack. The shell of porcelain must be attached and held firmly to the plunger rod. If allowed to run "dry" in the pump, it is liable to overheat and crack. The connections should be of some proved acid-resisting material. If care is not used in selecting the connections, corrosion may cause the failure of the connecting part, allowing the shell to wiggle and crack. Little packing trouble is encountered with a plunger of this type. If it costs, say, $150 to install a 10-inch porcelain plunger, and $125 to repack a pump, it can readily be seen that if packing troubles and "corrosion of plunger" troubles can be reduced, the extra cost is soon made up. The plunger rod may be made of a material such as a high-chromium-nickel-silicon steel. Such a rod was recently removed from a pump in the Edna No. 2 mine after four months of service. It had failed at the threads, but not elsewhere. On bronze rods it was customary to obtain about one month's service under the same conditions.

Another serious problem is that of the corrosion of pipes. Ordinary iron or steel pipe, or even wrought-iron pipe, does not last long in very acid water. By lining the pipes with wood it is possible to obtain a satisfactory period of service, providing the pipe can be kept on a grade so that there is no trap. Wood pipe

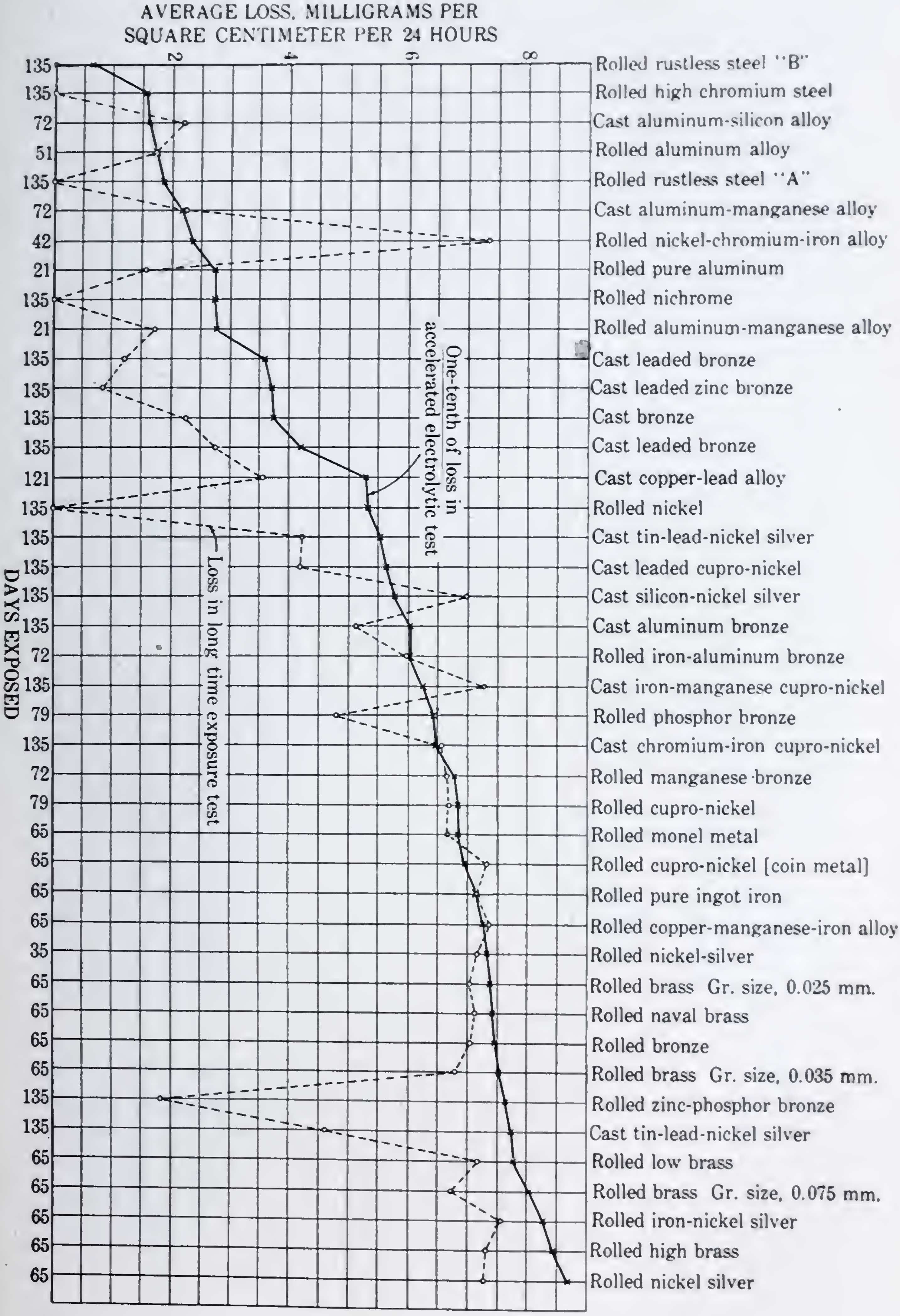

Fig. 13. Comparison of Corrosion Losses in the Accelerated Electrolytic Test with Losses in the Long-Time Immersion Test in Edna No. 2 Mine Water.

will have a tendency to clog up, if a dip or trap of any kind is in the line.

Substitutes for the wood-lined pipe or for iron or steel or wrought-iron pipe have been suggested. Lead-lined pipes might be expected to be of value, and would be if the joints were always tight and if no cracks or leaks developed as the result of buckling of the lead lining, or by attrition by sand or other material wearing through the lining. Lead-lined connections at the pumps might be expected to be of value, but the velocity and pressure of the water are high and the joints must be perfect, or leaks result. For pipe of small diameter, all-wood pipes can be used; say, up to four inches in diameter, or even above that, if bored. Stave pipe may fail, because even a tiny leak, or water from outside, may rapidly corrode the binding wire.

On pumps, acid-resisting alloys or porcelain can be substituted for the materials which fail rapidly. In pipe-lines, wood can be used, but for track corrosion there is nothing cheap enough which can be substituted. Track will corrode very fast if exposed to the action of acid water. Obviously it is expensive to tear up old track and buy and install new track. The remedy for track corrosion seems to lie in grading the track out of the way of the water. Frequently this can be done by shooting down the roof and building a ditch line alongside the track. In many cases the expense of grading would be more than the amount saved, but on main haulage-ways care in the grading may save considerable expense.

There are paints which will resist the action of acid water fairly well, if abrasion and friction or strains do not break the film of paint. Of course, paint is widely used, and if properly chosen will aid considerably in lengthening the life of some of the equipment exposed to the action of the acid water.

The corrosion of other equipment, such as shovels, bars, picks, car-wheels, etc., can best be avoided by keeping them out of the water rather than by attempting to substitute a resistant material.

The question as to the effect of acid mine water on concrete, especially when used in dams and stoppings, has not been definitely answered. From such information as is available, it would seem that, if the mixture is correct, there is not much trouble experienced.

Frequently, it is necessary or desirable to use mine water in the boilers of the power-plant. Of course, if the water is acid it will quickly corrode the boiler tubes unless previously neutralized. This neutralization can be accomplished by treating with lime rock, as is done at the Calumet mine of the H. C. Frick Coke Company. The resulting precipitate finds a limited market.

It has been suggested that if the water were neutralized underground the pumping equipment would not be corroded. Lime-rock and blast-furnace slag have been suggested as suitable neutralizing agents. There are serious objections to attempting to neutralize mine water underground: (1) large settling and overflow tanks are required, which would involve considerable extra expense in excavating the room; (2) water would probably have to be pumped to one central sump before treating, so the corrosion of pumping equipment would be only partly eliminated; (3) the neutralizing agent would have to be taken into the mine and the product of neutralization removed, involving considerable extra transportation or hoisting.

SUMMARY AND CONCLUSIONS

1. The recent corrosion investigations of the Bureau of Mines have been briefly reviewed, and the methods of testing metals and alloys in acid mine water described.

2. During the course of the investigations mentioned above many facts of interest were gathered in the field, and these, when correlated with the tests, have led to some suggestions on the solution of certain problems of corrosion confronting the coal-mining industry. These suggestions may be summarized as follows:

a. There are certain corrosion-resisting alloys; namely, a high-silicon cast-iron, a high-chromium steel, high-chromium-nickel-silicon steels, and a nickel-chromium-iron alloy, which may well be substituted in pumping equipment in place of the more readily corroded materials.

b. Wood-lined pipe is the best remedy for pipe-corrosion troubles, but there is much room for improvement here.

3. There seems to be no cheap substitute for iron and steel equipment such as tracks and car-wheels, and hence nothing can be done except to keep them out of the water as much as possible.

4. The possibilities of neutralization of acid water are discussed and it is noted that, at the present at least, underground neutralization is impracticable.

ACKNOWLEDGMENTS

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DISCUSSION

Mr. J. O. Durkee, *Chairman*:* This very valuable paper should create considerable thought among those of us who have trouble with mine water, and I am sure Mr. Enos will be glad to answer any question you may wish to ask concerning the corrosion in mines.

Mr. C. P. Fuller:† Have you tested "Duraloy" or "Illium," patented alloys, which are supposed to be acid resisting?

Mr. George M. Enos: Since I do not know the composition of either one, I cannot say whether we have tested them or not.

Mr. C. P. Fuller: They claim a lot, particularly for "Illium," for use with acids.

Mr. Philo Kemery:‡ What per cent. of the failure of the machinery and equipment would you say is due to corrosion and what per cent. to abrasion? Is the effluent clear?

Mr. George M. Enos: In the long-time tests very little of the failure can be attributed to abrasion. In the corrosion of a rod in a pump, for instance, that is something that only investigation can answer. Very little of the losses in the long-time corrosion tests, and none in the accelerated electrolytic tests, can be laid to abrasion from the solids carried in suspension. The color of the mine water is due to the dissolved salts rather than to anything that is carried in suspension. It is usually due to the ferric sulphate. It is true that it would be hard to distinguish between abrasion and corrosion of the piece.

Mr. Max Hecht:§ The author is to be complimented on the scope and nature of the work he has undertaken and presented to the Society. Most operators in the Pittsburgh district can

*Mining Engineer, Pittsburgh.
†Sales Engineer, Harris Pump & Supply Co., Pittsburgh.
‡Superintendent Open-Hearth and Crucible Departments, Crescent Works, Crucible Steel Co. of America, Pittsburgh.
§Chemist, Duquesne Light Co., Pittsburgh.

review the work profitably and correlate some of their corrosion problems. My particular interest in this subject is the effect of non-ferrous metals used in condenser practice, principally the brasses, when utilizing the polluted water supplies in the Pittsburgh district for condensing purposes.

One phase of the subject which the author has not touched upon is the effect of the organic matter found in the water-supplies, resulting from domestic and industrial wastes, and a pertinent question is, can the rate of corrosion, particularly on the brasses, be determined by the electrolytic method discussed to-night, indicating the effect of organic deposits.

Interesting analogies can be made by rearranging the weight-loss experiments. This has been done, and it appears that the copper-zinc-tin alloys show a rate of weight loss lower than most of the non-ferrous alloys, with the possible exception of nickel-chromium.

Comparing the observed mine-water tests of the brasses in actual operating conditions, keeping in mind that the brasses are exposed to polluted river waters, the acid at times approximating one-fiftieth the amount of total acidity as reported in the lowest acid water dealt with, it is found that Admiralty mixture, copper, brass (65 copper, 35 zinc), Muntz metal (60 copper, 40 zinc), give the best service in the order named, covering a period of 12 years; in other words, corrosion trouble with the materials used was found to increase in the order of the above-mentioned alloys.

Mr. George M. Enos: The points just mentioned are very interesting. Of course you realize that in a paper of this kind it is impossible to put in every point that might be made. In regard to the organic matter, I had occasion near the conclusion of the tests to notice a deposit on the body of the test-pieces in the Edna No. 2 mine. This deposit was not noticed in the other mines. It bothered us for a considerable time because we did not know what it was or what to do with it or what effect it had on the corrosion rate. I doubt if it had very much effect on the corrosion at all. The material looked like rotten oysters, and smelled somewhat the same. I gathered some of it and brought it in to the Bureau and an attempt was made to identify it. We finally managed to decide that it was an organic growth—a fungus of some sort probably.

I do not want to be too specific, but it seemed to be colloidal in nature and to be a living organism. Just what the effect would be on corrosion I do not know. No tests have been made to ascertain the quantity formed or the importance of this organic growth. To the best of our knowledge it did not affect the results.

In regard to the condenser tubing, I might mention that we have recently made a rather exhaustive test on the effect of grain size in brass, and I do not want to discuss that to-night because the data have not been completed, but if any of you are particularly interested I will be glad to talk it over.

Mr. Max Hecht: It has been indicated that a probable low rate of corrosion resulted from the coating of deposit found on the test-pieces. Do you believe that when the metals are in service, as in pump valves, plungers, etc., a coating will remain?

In condenser practice, in order to maintain high condenser efficiency, the surfaces are frequently cleaned. It is probable that the corrosive action of the condensing water thereby accelerates the failure of the tubing.

The electrolytic method of measuring the resistance which various metals offer to corrosion is one which permits a ready measure of the durability of an alloy, without a great outlay of money for extensive tests.

Mr. George M. Enos: I once asked Dr. Wilder D. Bancroft what a film on corroded metal is, and he used a lot of words telling me what it is not. I have formed a sort of definition for the difference between a film and a coating. I differentiate between a coating and a film in this way:

A coating is composed of corrosion products resulting from the reaction of the corroding media and the metal, or precipitates from the solution, or a combination of both. The particles composing it may be colloidal. It is of such thickness that it can be measured by a good metallurgical microscope.

A film is less than 0.3 millimicron thick, and may or may not act as a protection. It is conceivable that a film of ultramiscroscopic thickness might act as a protection against corrosion, or might accelerate it. A film might be entirely gaseous in composition, whereas a coating would be liquid or solid. Of course the above

conception of films and coatings is empirical, but it is convenient to use in considering corrosion phenomena.

Considering your question as referred only to a coating as I have defined it, I would say that it would be extremely doubtful if a coating would stay on a pump rod. Also in the interior of a pump, I doubt very much if any coating would remain if any sand or other abrasive material came along. The coating would probably be brushed off. I have observed that the coatings will remain in some instances and are very hard, and the question is one which is not settled yet. It may, and probably will, vary with the nature of the material. In brass tubes such as are used in condenser practice the chances are pretty good that the coating (or film) was desired because it would be of a protective nature. The coatings which I have observed on brass in the mine-water investigations are very loose and easily removed and certainly would not afford any protection, although they might accelerate corrosion by galvanic action or some such phenomenon. Coatings on bronze such as I showed on the screen are hard enough and impervious enough so that they would act as a protection. Whether they would stand the action of abrasion or not I do not know.

Mr. J. O. Durkee: There is one thing I did not get quite clear in the paper; that is, the result of alternating. For instance, if you have a pump that will empty the entire sump in three or four hours, or six or eight hours, out of the 24, and the remainder of the time the mechanical means for taking the water out of the mine are practically down, have you any idea as to the result of that—whether, if we would use a slower pump and take up the whole 24 hours in pumping water to the surface, it would be to our benefit more or less?

Mr. George M. Enos: That is a question I cannot answer at the present time. Experiments with actual pumping equipment are planned, but are not yet under way. It is known that in corrosion tests in sea-water there is a vast difference between having the test-piece immersed in sea-water all the time and having it exposed to the atmosphere part of the time. In considering the theoretical factors which might enter into the corrosion process it seems reasonable to expect that alternating immersion and expo-

sure to the atmosphere would affect the corrosion rate. It might be predicted that there would be slightly more corrosion where the exposure was alternating. That would simply be reasoning from the sea-water tests and not from any mine-water data. Of course something might be said on the other side, that there might be more dissolved oxygen and ferric sulphate, and if the pump were run longer there would be more opportunity for corrosion. I cannot answer the question definitely.

MR. J. O. DURKEE: That is a problem that means dollars and cents to the man that has water to lift out of a coal-mine. I have been thinking that corrosion is accelerated by the flow of water alternating with draining the pipe.

MR. MAX HECHT: As Mr. Enos intimates, during the period you are not operating you can expect evaporation of the water with resulting concentration of the acid constituent, which might accelerate corrosion. In fact, in condenser practice, we try to keep the metals wet all the time to avoid that particular situation.

MR. GEORGE M. ENOS: In that connection I was talking the other day to a mine superintendent who remarked that when porcelain plungers were used it was necessary to keep them covered with water all the time the pump is in operation. If the pump is out of the way and a man is not kept watching it, if the pump runs dry and is not stopped pretty quickly, it would heat up and the porcelain would be apt to crack.

MR. J. O. DURKEE: I have never had any experience with porcelain, but it seems to me that if the pump were stopped for any length of time, and if the porcelain were a little deteriorated, it would have a tendency to break or spall. Left running without water there is no question at all that it would be destroyed. Is this porcelain plunger a close fit?

MR. GEORGE M. ENOS: It fits very closely. They do not have much trouble with packing. That is one of the advantages—to get away from packing troubles.

MR. J. O. DURKEE: I was wondering why you did not say more about the effect of corrosion on the alloy steels—nickel, chromium and iron alloys. The effect is very slight, I believe.

MR. GEORGE M. ENOS: The corrosion losses on the "Rezistal" steels—that is, nickel-chromium-silicon steels—and also on high-chromium steels without nickel and silicon, were about the same. These materials, I should say, give considerable promise for use in pump parts. From these materials you can get perhaps four times as much service for some parts. In service tests the plunger rod made of nickel-chromium-silicon steel lasted about four times as long as the ordinary bronze plunger rod, and the only place it failed was in the threads.

MR. J. O. DURKEE: I had some experience with chrome-iron alloy. I cannot say whether there was any silicon in it or not. This was with sea-water and we made spray tests in the laboratory with salt water, and if we could detect anything that showed color we considered that corrosion.

MR. GEORGE M. ENOS: In our long-time tests, particularly at Calumet mine, we obtained all sorts of color, but the actual loss was very small.

MR. J. O. DURKEE: In your tests have you ever found out what is the difference between a wood plunger pump and your porcelain or bronze as to how the service would compare? Have you ever seen a wood plunger used?

MR. GEORGE M. ENOS: I have not. Speaking of this work in general, I might say that the first year was devoted to more or less empirical tests. The work has progressed this year more on the theoretical side and much of the work has been done in the laboratory and in correlating data. Next year we plan to go into the field and put these parts into actual service in mine pumps and other places. The work has not commenced yet, but it is outlined. We hope in another year to tell you a great deal more about it.

Mr. A. E. Blake:* Would not calorized or chromized steel resist the corrosive action of acid mine water?

Mr. George M. Enos: I will ask Mr. R. J. Anderson to answer that. He knows more about calorized metals than I do.

Mr. R. J. Anderson:† I do not think so. I think mine water would readily go through the calorized surface; and, if so, considerable electrolytic action would be set up, so that calorized materials would be out of the question.

Mr. A. E. Blake: You are supposed to have a neutral oxid coating.

Mr. R. J. Anderson: I understand that, but I do not think it is perfect.

Mr. George M. Enos: What is the chromized material?

Mr. A. E. Blake: Chromized steel is made by a process identical with the calorizing process, with the substitution of powdered chromium for powdered aluminum. It has certain qualities which ought to make it very popular, although its use has not been pushed to any great extent thus far.

Mr. C. P. Fuller: Getting back to the subject of coatings, we have observed in connection with bronze impellers out of centrifugal pumps, which have worn out and been returned to us for inspection, that of impellers supposed to be of identical composition one will show a yellow color, while another may be decidedly red or ruddy. Is this color a coating, or is it due to what you call selective corrosion? The reason for this question is that we cannot detect any difference in the color from the throat of the impeller where the velocity is high, and this would seem to indicate that if the color is due to a coating, the coating is not appreciably affected by the rubbing action of the water.

*Pittsburgh Representative, U. G. I. Contracting Co.
†Metallurgist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

MR. GEORGE M. ENOS: In laboratory accelerated electrolytic tests I have noticed that the material left in place, or deposited on the anode in the case of copper-bearing alloys, is frequently very red and that the material is undoubtedly copper in some stage of oxidation, and possibly metallic copper. On other materials the coating usually is not red. With varying concentrations of mine waters it is possible that variations in the color of the corrosion product might be produced. It would be interesting to examine corroded pumps parts and note the colors of the corrosion products.

MR. C. P. FULLER: Did you investigate any of these colors?

MR. GEORGE M. ENOS: We haven't any opportunity. We would like to get in touch with anybody who will furnish us with pieces of that kind.

MR. O. B. J. FRASER:* Have you investigated the influence of the amount of ferric iron in mine water on the different alloys? A good many of them are bronzes and copper-nickel alloys which are highly susceptible to corrosion in acid solutions containing ferric salts, whereas solutions of the same acidity, but free from ferric salts, have very little action on them.

MR. GEORGE M. ENOS: The subject of the influence of the amount of ferric iron upon the corrosion rate of metals and alloys in acid mine water has not been investigated as a separate problem. We are aware that the concentration of the ferric iron is an important factor, but as the concentration varies from day to day in the mine water, in the tests made in the field the results are comparable because made in the same mine water. Calculations made on the corrosion losses for many individual alloys and for groups of alloys such as brasses, bronzes, etc., indicate that the corrosion is directly proportional to the free acid content, where the factors are all constant except the composition and concentration of the mine water. Many more acidity determinations were made than ferric iron determinations, and it is possible that had

*Mellon Institute of Industrial Research, Pittsburgh.

enough iron determinations been made a relationship could have been established. It may be well to point out in this connection that corrosion is simply oxidation, and that ferric sulphate is an excellent oxidizing agent. Ferric sulphate in solution hydrolyzes and finally comes to an equilibrium when a certain relation between the concentration of the free acid and the concentration of un-ionized ferric sulphate is attained. In this way the free sulphuric acid, and the total acidity due to free sulphuric acid plus sulphates of iron and aluminum, take account of the potential oxidizing power of the solution.

Mr. O. B. J. Fraser: The reason I asked is because figures given out by the manufacturers of the alloys which showed best in the mine-water tests, and also the results of tests which I have run myself, rank certain of the metals in the reverse order of their performance in the mine waters.

Mr. George M. Enos: Were the tests in ferric sulphate?

Mr. O. B. J. Fraser: My tests were accelerated tests in the laboratory in which the metals were corroded in agitated, air-saturated solutions at ordinary temperatures. In papers presented before the American Society for Steel Treating in 1921, Dr. C. M. Johnson has published figures which show the corrosion rate of the "Rezistal" alloys (which are of the class called "highly alloyed Cr-Ni-Si steel" in Bulletin 4 of the Carnegie Institute of Technology Coal-Mining Investigations) to be from 2.5 to 4 times that of "Monel" metal in 10 per cent. sulphuric acid solution. My tests covering concentrations from 5 to 50 per cent. H_2SO_4 show similar figures. On the other hand, the introduction of even small amounts of ferric sulphate into sulphuric acid solutions increases the corrosion rate of "Monel" metal to from 3 to 40 times that in solutions of the same total acidity, but without the ferric salt. In other words, the ferric sulphate content of the mine waters, rather than the total acidity, is the prime factor in ranking (as in Bulletin 4) many of the alloys listed. "Monel" metal and several of the bronzes and copper-nickel alloys are in service in many fields, where they are withstanding with the utmost satisfaction sulphuric acid solutions of the concentrations encountered in the mine-water

tests, but with no ferric salts or other easily reducible compounds present.

MR. GEORGE M. ENOS: I think there is undoubtedly a relation between the ferric sulphate concentration and the corrosion rate. Just what that relation is and how it is varied by the concentration of the sulphuric acid, and what is the effect of one variable on the other, is something I can't answer.

The results given in Bulletin 4 apply to mine-water corrosion and should not be interpreted to cover cases where only sulphuric acid or only ferric sulphate is in use, although in a general way it might be said that they would be applicable where there is low concentration of sulphuric acid, as in river waters of this region.

MR. J. O. DURKEE: There is one other question that I have in mind. In my experience in operating I have found myself under 1200 to 1400 feet of cover and have observed those constituents that destroy pipes and pumps and things of that kind. I observe that Mr. Enos's investigations were in three comparatively light-cover mines, and I know from practical experience that there is where we find the most difficult water to handle. It seems to me that all the harmful constituents which occur in an overburden of 100 to 150 feet would occur also in an overburden of 800 to 1200 feet, and I think that Edna No. 2 would not have anywhere more than 200 feet of cover; and yet that is, as you see, the most destructive mixture that you find. I do not know the cause, but I know it is true.

MR. GEORGE M. ENOS: In the case of these deep mines, how long have they been opened up? Have they been opened as long as the Edna No. 2? Do they have drainage from an old mine?

MR. J. O. DURKEE: Yes, they have the gob workings just the same. The Gates mine must have from 1000 to 1100 feet of cover in the deepest part and it is very easy on pipe-lines, whereas the Bitner mine, which has a very light cover, would tear them all out. The constituents that are over one should certainly be over the other.

Mr. George M. Enos: It is pretty well established that it is action of the air and the water on the pyrite in the coal itself and along the gob which forms the acid mine water, rather than that the acid water comes from the overburden. I do not know that there is any actual information on that. It is pretty generally assumed that the acidity in the water is due to the oxidation of the pyrite, and this takes place most easily in the old workings. Then water draining from the old workings becomes acid.

Mr. J. O. Durkee: I think that we should be very proud that the Bureau of Mines has seen fit to send one of its scientists to discuss this very practical problem. I know that we all realize that this institution is co-operating with us and perhaps will be able to assist us to save more money in our industry. I know these men have been very prompt to render assistance at any time they are called upon and we feel complimented that they do so.

Mr. W. M. Austin:* I have had some experience in the use of steels containing about 12 per cent. of chromium. This was in marine work where the apparatus of which this steel forms a part might be rendered inoperative by even a small amount of corrosion. We found it possible to get a piece of this steel to stand a salt-water spray for 96 hours without showing any evidence of corrosion on a polished surface. The polish was just as bright at the end as at the beginning of the test.

I imagine that mine water has been found to be more severe than ocean water on the high-chromium steels.

On the general subject of corrosion certain cement manufacturers have claimed that structural steel encased in cement would not corrode, because they claim that ordinary corrosion of iron from moisture in the atmosphere will not occur unless CO_2 or some other acid is present along with the oxygen and nitrogen. It is claimed that any CO_2 present in the air will combine with the $Ca(OH)_2$ in the cement and fail to come in contact with the iron. I would like to ask if any investigation along this line has been made in connection with corrosion in the mine industry?

*Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Mr. George M. Enos: We have not had occasion to investigate the subject mentioned in connection with the mine-water corrosion; although we have, of course, considered all the theories of corrosion, and have a very complete bibliography of corrosion in general.

Mr. W. M. Austin: Portland cement is at least 60 per cent. lime (CaO), and some of this 60 per cent. is free when the concrete is first made—that is, uncombined with the iron, silica or alumina that forms practically all the rest of the cement. This fine lime is probably $Ca(OH)_2$ until it has gradually been turned into $CaCO_3$ by infiltration of CO_2 from the atmosphere.

Mr. George M. Enos: The question of the necessity for the presence of CO_2 in the corrosion of iron by moisture and the atmosphere has been debated by various authorities. It is my opinion that while CO_2 may accelerate corrosion—e. g., catalyze the reactions—it is not necessary to have it present for corrosion to start.

BATES TEST ROAD

By Ralph R. Benedict*

With the large amount of money made available in the state of Illinois by the passage of a $60,000,000 road bond issue, and the various government allotments to the state for road construction it was decided early in 1920 to undertake the construction of an experimental road of unprecedented magnitude. The construction of the Bates road, so called on account of a small station by the name of Bates, near the west end of the road, was started in June 1920 and finished in July 1921. The original road was approximately two miles in length and included 63 sections, each approximately 200 feet long and representing all of the types ordinarily considered as suited for modern traffic conditions as follows:

In the plan of the various sections and in the scheme of testing, it was held in mind that as much information as possible should be obtained, looking forward to the determination of the fundamental principles governing the design of payments of any of the general types included in the tests.

The fundamental laws obtained from the Bates test will enable a designer to plan a pavement confidently, knowing the general conditions applying at points where pavements are to be laid, suitable to general conditions.

Before actual traffic was started, a large amount of scientific research was carried out both as to the construction and subsequent behavior of the road. As so much of this material has appeared in the technical press from time to time, I will not attempt to go into detail regarding these results, but will briefly review some of the most important points or lessons learned.

Subgrade Moisture. From the several hundred subgrade sampling stations in the Bates road it developed that the moisture content of the soil under the pavement varied from approximately 32 per cent. to over 40 per cent. of the dry weight of the soil.

*Assistant to Chief Highway Engineer, State of Illinois, Springfield, Illinois.

Also, it was developed that the moisture content of the subgrade soil in proximity to edges and cracks was at no time materially different from that observed elsewhere. Another very interesting point in this connection is that the moisture content of the subgrade did not seem to be affected by the frequent rains which occurred.

It was found that even with a tile drain immediately under each edge of the pavement, and with the trench backfilled with cinders, the moisture content of the subgrade soil was not reduced in any case below that which was obtained under similar pavement without such tile drains.

Subgrade Bearing Power. A soil having a given moisture content may, under repeated loads, have a fairly definite elastic limit. The elastic resistance to deformation of subgrade soil in the Illinois corn belt is probably less than one pound per square inch when that soil contains 40 per cent. moisture.

Subgrade Uniformity. There were installed in the Bates road many subgrade cylinders, each having a brass disk in contact with the subgrade and a reference plug screwed in the cylinder in such a manner that measurements taken from the plug to the brass disk would show the relative position of the subgrade and pavement slab at any time. The results of the observations taken over a year's time show a periodic separation of the pavement slab and the subgrade due to warping of the slab under temperature changes. The erratic movement of the brass disks relative to the slab leads us to the conclusion that not only is the slab itself constantly warping, but that the subgrade also is unstable, even though there be no traffic on the road.

No heavy grades occur throughout the original two-mile stretch; the deepest fill was about two feet, and the deepest cut about 18 inches. After the rough grading was done, the entire subgrade was plowed, harrowed, rolled, and wetted the day before the slab was laid.

Temperature Effects. It was discovered that a working phenomenon caused by the more rapid heating and cooling and consequent expansion and contraction of the upper layer of the slab was taking place every 24 hours, or when there was a change of 20 degrees in temperature. By repeated loads on the corner of a

slab, the results showed that at night the slab corner under load was at a higher elevation than the unloaded corner during the day.

To visualize this condition, photographs were made of the edge of an eight-inch pavement slab and the subgrade below. A white card was rigidly attached to the slab, and one was fixed to the subgrade at some distance below the base of the pavement. The black line was drawn across the two cards at midday while the sun was shining. Then a photograph was taken at midnight; a distinct crack in the earth subgrade a short distance below the bottom of the pavement, is shown, and also the offset in the line caused by the upward movement of the slab.

Impact. Specifications of the Illinois Division of Highways provide that the variation of the elevation of the surface of concrete pavement shall not exceed 0.25-inch, and the more careful construction methods are reducing these variations very materially.

Results to date show that the above variations are not of extreme importance, and that drops of a moving load up to 0.375-inch do not cause the same deflection as the same load applied statically.

The usefulness of a pavement is destroyed only when it becomes so broken or disintegrated that it no longer affords a smooth and comparatively unyielding surface. Illinois, for about six years, has not provided for transverse joints; yet transverse cracks do not average less than about 30 feet apart. While the breaking of the pavement into slabs of large area may be detrimental only on account of appearance and slightly increased maintenance costs, yet the breaking down and pulverizing of comparatively small areas at corners and the consequent reconstruction at these places cause serious traffic delays as well as expense.

Testing. Testing by means of "artificial" truck traffic was started in March, 1922, and continued until September. Then repairs were made to those sections not completely destroyed, and additional sections were added. The trucks started with a minimum load of 2500 pounds on each rear wheel, and this load was increased after each 3000 round trips until the maximum load was imposed, which was four tons on each rear wheel. No traffic was permitted on the pavement except the controlled truck traffic incident to the investigation.

Before the completion of the tests originally planned, the preliminary work suggested the desirability of a special design for concrete slabs. One section of this design was built in the spring of 1921 and tested with the remainder of the road in 1922. The completion of the traffic tests last fall provided such a wealth of data and conclusions that approximately 2000 feet of additional test sections were added during the fall of 1922. These sections embodied features of design based upon the previous traffic tests, and they are being tested to destruction in an effort to substantiate conclusions already drawn.

As a result of the truck-traffic tests it was revealed that in the macadam-base types of pavement the total thickness of the paving material was not the most important factor governing the load-carrying capacity of the road. Other factors, such as the amount of moisture content in the subgrade soil when the pavement was laid, apparently had more influence on the load-carrying capacity than thickness alone, inasmuch as sometimes sections of this type having the greatest thickness failed earlier than the sections having a lesser thickness. The truck-traffic tests on these groups of sections indicated also that the best of these sections was hardly equal to the weakest sections of pavement having a concrete base or composed entirely of concrete. The sections having concrete bases or composed entirely of concrete are generally called rigid types of pavement. The truck-traffic tests showed unmistakably that in such pavements the load-carrying capacity is in proportion to the square of the thickness of the slab. For example, a pavement composed of an eight-inch total thickness of concrete or over might be assumed to be four times as strong as a pavement having a four-inch total thickness of concrete.

The most important and far-reaching discovery was that of the comparatively extreme weakness of the edges as related to the strength of the mid-portion of the slab. All sections of rigid types that showed any signs of failure, first failed along the edges, the breaking up of the remainder of the pavement being directly traceable to this initial failure.

Of the original 63 sections, only nine came through the traffic test of last year. Under the traffic so far this year, two

of these sections have failed. The following general conclusions seemed justifiable to Mr. Clifford Older, Chief Highway Engineer, at the end of the traffic runs of last season.

Bituminous Filled Brick on Macadam Base. A difference in the thickness of the base, thickness of the brick, or type of brick apparently has no effect upon the load-supporting capacity of these sections. All five sections failed at approximately the same time and to the same extent.

Asphaltic Concrete on Macadam Base. No consistent ratio of strength to thickness of base appears. Apparently, traffic-supporting capacity increases with an increase of thickness of asphaltic top.

Asphaltic Concrete on Concrete Base. It is evident that increased base thickness is accompanied by increased strength. The assumption made when test sections were originally laid out—that bituminous top pavements would have a strength equal to the strength of the base if the same were increased by one inch—is only partially borne out by the results. It appears that an allowance equal to one-fourth of the top thickness is fully as much as would be justified.

Bituminous Filled Brick on Concrete Base. The sections having this type of top, as was the case with the bituminous concrete top series, showed a distinct ability to resist progressive destruction.

Monolithic Brick. The original assumption that the brick surface in this type of pavement acts as a unit with the concrete of the base, thus forming a truly monolithic slab having the same carrying capacity as an equal thickness of concrete, was disproved early in the traffic tests. In comparing an added inch of brick with an added inch of concrete base, the total thickness remaining the same, it was noticed that the thicker base section has the advantage.

Concrete. Soon after traffic started, it developed that the sections containing special cements or other chemicals showed less strength than plain concrete sections of the same thickness. Sections containing certain special features of design, consisting of transverse and longitudinal joints with marginal steel, showed greater strength than plain concrete sections of the same thickness.

DISCUSSION

Mr. B. A. Ludgate, *Chairman*:* It is through Mr. Blum, of Blum, Weldin & Company that we are favored with this paper to-night, and probably he may have a few words on the subject.

Mr. L. P. Blum:† It was my good fortune in January of this year to attend the Highway Congress in Chicago and hear Mr. Older's paper on the Bates test road. The paper was so interesting and so impressed me that it seemed worth while to make the journey from Chicago to Springfield to go over this road with a representative of the Illinois State Highway Department. I was very much interested in it and in general I can not help indorsing the conclusions reached. The impressive conclusion to me is the absolute failure of the so-called elastic bases. There is no doubt in my mind that an inelastic base is necessary for a permanent road to withstand modern highway conditions, and there is no such base to-day that can be built with the same economy, I believe, as a concrete base.

In speaking of the macadam failures which have been spoken of we ought to differentiate between a solid macadam with a solid Telford basis, such as we have in the older portions of the country which have been in for half a century or a century, and which have withstood traffic gradually increasing until they are settled into a very solid base. It would be foolish to consider them as being in a class with the Illinois macadam roads spoken of to-night. The conclusions arrived at as to such base I think were very well indorsed at the conference of highway officials called by Governor Pinchot which met in Harrisburg in March of this year. There were differences of opinion as to what the wearing surfaces should be, but the conclusion of those present was that any macadam base, or, as they put it, any of the elastic bases must be considered as secondary types of construction.

Now if we are going to use concrete for a base it seems to me that in new suburban construction we might just as well use

*Assistant Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh.
†Blum, Weldin & Co., Pittsburgh.

concrete as the wearing surface. We are past the experimental stage of concrete construction. The *Engineering News Record** recently published the records of cost of maintenance of the Wayne County road in Michigan, 11 years old, which carries traffic up to 5000 vehicles per day (which is comparable to the Bigelow Boulevard traffic) which show that the annual maintenance of such road was only $500 per mile.

I am well aware of the principal objections to concrete roads which have been made in this vicinity—the unsightliness of the cracks which are bound to appear and which are filled with a black material. But it seems to me not a debatable question that such slight unsightliness is not worth the cost of surfacing such roads with a material which will maintain a surface free from cracks. It seems to me it is the business of the engineer to educate the public to understand that those cracks are not structural defects, as the speaker has pointed out.

It seems to me in passing that the Bates road test is a most impressive one—possibly the most impressive test that has been made in this country—in that it more nearly simulated traffic conditions than any other test road ever built. In shape and physical conformation it was like all the other roads in Illinois, in contrast to the Pittsburgh (California) road or the Arlington road, which are better described as circular tracks. In the matter of loads, the loads used in the test of the Bates road were rational loads—not as in the Pittsburgh (California) experiment where unusually excessive loads were used to test the pavement. Furthermore, the Bates road tests were tests of foundations as well as surfaces. Some of the other roads were purely surface test roads. Probably the most important feature is that it was a thoroughly regulated traffic. The Philadelphia test road was simply open to the promiscuous traffic that came along, with no attempt to regulate or count the traffic. In the Bates test it was scientifically regulated and counted traffic.

But there are certain features of the Bates test road which must be taken into account if you are seeking to apply its results to our Western Pennsylvania territory. The principal difference is in topography. The Bates road is a through-cut road while in

*Vol. 90, p. 739-740.

Western Pennsylvania especially on account of our rugged topography our roads are principally half cut and half fill roads. They are on steep grades as compared with this level Bates road and the results obtained on the Bates road must be interpreted in the light of our Western Pennsylvania conditions; for instance, the absence of reinforcement. On the Bates road I should have liked to see heavy trucks equipped with chains, which are allowed in Pennsylvania, suddenly started and suddenly stopped, to see what the effect of those chains would have been on those slight temperature cracks. I do not believe they are structural defects but if neglected in any way under our Western Pennsylvania conditions they would cause the disintegration of our roads. I have seen very many roads in Western Pennsylvania fail at specific places under these conditions where the grade was suddenly steepened and the driver was compelled to change gear and you could mark that place of changing gear within 25 feet on some roads.

As to the standard section in comparison of width of concrete, 18 feet seems to be a rational width of roadway. Some of our road engineers are going it a little bit strong in their advocacy of 20 feet. With a state law which limits the width of vehicles to seven feet six inches, it seems to me an 18-foot roadway is a rational width, excepting of course on very sharp curves where the width should be increased.

The width of the dirt shoulder is given as six feet in some of the publications that I have seen. This is not important in flat country like Illinois, but in Western Pennsylvania it seems to me that that width of earth shoulder could be reduced as low as three feet, when we consider that an increase of 25 per cent. in the graded width of our sections frequently means the doubling of the amount of grading required.

Regarding the thickness of concrete, the Pennsylvania state specifications place a thicker concrete in the middle and thinner at the edges—seven inches in the middle and six inches at the edges, whereas in the Illinois experiment they go the other way. I believe, however, in view of the results of the Bates experiment that this Illinois section is the more logical.

While other states have been increasing the reinforcing with each year—Pennsylvania in one year doubling its reinforcement, going from 28 to 56 pounds per 100 square feet of surface—the Illinois experiment throws away all reinforcement and limits us to a few rods. I do not know whether this would be good practice in Pennsylvania to-day. I believe it has been shown to-night that those sections which were integrally reinforced have fewer temperature cracks than those sections which were not integrally reinforced—by that, I mean a mesh reinforcement. For the further purpose of taking care of the effect of the chains on our hills, I believe we are not yet ready to do away with integral reinforcement on Pennsylvania roads.

The center dowel joint is worthy of serious consideration. It is a new thought to me. It is unquestionably true that any road built over 20 feet in width should have a center joint. I would like to see a little bit more of the theory by which a center joint is figured out in a road 18 feet wide. It seems to me there would be constructional difficulties in those separations—a retarding of the progress of construction which would make such a joint questionable.

The other point which the speaker brought out is quite important—the question of rich versus lean concrete mixture. There is no place where we can save in the making of roads more readily than in the proportion of cement; but, if such saving in cement interferes with the structural integrity of the road, it becomes questionable. While I would not want to express a definite opinion on this subject at this time, I would state that I believe our Western Pennsylvania experiments tend to the conclusion that rich concrete is so much more certain and satisfactory in its results that I would go on a 1 : 3 : 5 mixture.

Mr. Ralph R. Benedict: That is a very excellent discussion. It brings up some points I should like to cover.

First, as to the question of changing the richness of mixture. A lean mixture is advocated only for pavements having other wearing surfaces, not for concrete road surface. With a brick or asphalt top, the mix of the base might be leaner but in no case should the wearing surface be made lean.

Next, regarding the constructional difficulty of slowing up progress in the placing of the central joint. In 10 hours one contractor laid 1585 feet of 18-foot concrete pavement with the joint in the middle and the bars along the side, so I don't believe there was any slowing down of the progress due to construction of the center joint. We believe the center joint is worth every cent it costs, if for nothing more than to divide the traffic. We are going to the expense of applying a bituminous painted line in the center of all 16-foot rural roads previously built.

In the construction of the center joint we originally used a strip of corrugated metal roofing cut to the required depth, and this gave a tongue-and-groove effect. Now there are half a dozen designs of center joints put out by the steel manufacturers. There are no patents covering the different shapes. The idea of the tongue-and-groove longitudinal joint is to give support to each of the slabs along the center.

I think it is true that you must take with a grain of salt any conclusions that we have reached from the Illinois experiments as to their bearing on your topographical conditions with half cut and half fill as a factor. I still differ, however, as to the need of 56 pounds of reinforcement.

Mr. L. P. Blum: An interesting observation on the concrete section of the Bates test road is this: There is practically no abrasion of good concrete road surface, as is evidenced by the fact that paint marks to mark the location of expansion cracks were there clearly discernible after all the thousands of heavy loads had passed over the section of concrete.

Mr. Ralph R. Benedict: That is true under rubber-tire traffic.

REACTIVITY OF COKE IN RELATION TO BLAST-FURNACE OPERATION*

By G. St. J. Perrott† and Ralph A. Sherman‡

INTRODUCTION

The influence of the properties of coke on its efficacy as blast-furnace fuel has been given considerable attention, both from the standpoint of theory and that of practice. It is a well-recognized fact that the quality of the coke affects blast-furnace operation, but, despite the great amount of work and thought which have been expended on the subject, recognized specifications for metallurgical coke are as yet lacking.

In times past, the quality of coke was judged primarily from an esthetic viewpoint. A silver luster and metallic "ring" were highly prized attributes. We have now learned that the dull appearance of by-product coke is in no way detrimental to its utility as blast-furnace fuel and we are endeavoring to judge coke quality less by appearance and more by exact analysis and measurement. At the present time, considerable importance is attached to the "reactivity" of coke—that is, (1) its combustibility or rate of combination with oxygen and carbon dioxid at the tuyeres of the blast-furnace; and (2) its susceptibility to oxidation (or "solution") by carbon dioxid in the shaft, and to direct oxidation by iron ore.

This paper sets forth the prevailing views as to the function of coke in the blast-furnace, and the properties possessed by a desirable coke; and then discusses the problem in the light of recent data secured by the writers, both in the laboratory and at blast-furnace plants.

FUNCTION OF COKE IN THE BLAST-FURNACE

Coke performs two classes of duties in the blast-furnace; namely, physical or mechanical, and chemical.

*Published by permission of the Director, U. S. Bureau of Mines, Department of the Interior.
†Physical Chemist, Pittsburgh Experiment Station, U. S. Bureau of Mines.
‡Assistant Physicist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

Physically, coke is a fuel of low density which keeps the other constituents of the burden so separated as to permit easy passage of the gases; resists mechanical attrition due to the weight and grinding action of the descending stock; does not spall or decrepitate, fuse, or give off tarry matter under the influence of heat; and descends unchanged to be burned at the tuyeres.

Chemically, coke provides heat for the furnace reactions and carbon monoxid gas for reducing the ore in the shaft. Coke is burned in a relatively small zone (about 30 to 40 inches in diameter) around the tuyeres,[1*] forming carbon monoxid and small quantities of hydrogen as the final products of combustion.

Combustion takes place in two stages, which may be indicated as follows:

$C + O_2 = CO_2 + 97,200$ calories per gram-atom of carbon....(1)
$CO_2 + C = 2CO - 38,880$ calories per gram-atom of carbon..(2)

Reaction (1) is complete at about 24 inches from the nose of the tuyeres, and (2) is complete at about 40 inches. The coke ash is here melted, and combines with the limy slag from above to form the final resultant slag, which is tapped off at the cinder notch. In the zone of spongy iron, considerable sulphur is probably taken up from the ferrous sulphid in the coke.[2] In the combustion zone, the sulphur released from the coke is probably entirely taken up by the slag.

Ore in the stack is reduced according to the equations:

$$\left.\begin{array}{lllll} 3\,Fe_2O_3 + CO & = & 2Fe_3O_4 & + CO_2 + & 22,840 \text{ calories} \\ Fe_3O_4 + CO & = & 3FeO & + CO_2 - & 5660 \text{ calories} \\ FeO + CO & = & Fe & + CO_2 + & 2340 \text{ calories} \end{array}\right\} \ldots\ldots(3)$$

This has been called "indirect reduction," as distinguished from "direct reduction" by solid carbon where:

$FeO + C = Fe + CO - 36,540$ calories........................(4)

As the coke proceeds down the stack it is surrounded by the stack gases containing carbon dioxid formed from the reactions in (3). At temperatures above 900 degrees C., the following reaction begins to take place in the stack:

$C + CO_2 = 2CO - 38,880$ calories....................................(5)

This oxidation of carbon by carbon dioxid has been called "premature combustion" or "solution" of carbon, and is generally believed to be detrimental to furnace operation, because it absorbs

*See Bibliography at end of paper.

heat from the stack and prevents carbon from reaching the tuyeres.

A coke for blast-furnace use must be of sufficient mechanical strength to resist crushing in the furnace; must be low in ash and sulphur; must be resistant to the oxidizing action of the carbon dioxid in the stack gases; and must burn rapidly at the tuyeres—this, in brief, is the opinion of those versed in the theory and practice of the blast-furnace. Whole volumes have been written elaborating these ideas, but the court of last resort for judging the value of a coke is the blast-furnace itself.

A word as to the difficulty of determining the relative merits of cokes from blast-furnace operating data may not be out of order. The efficiency of coke is judged by the weight of coke required to produce a ton of iron and the quantity of iron made per day. This is determined in turn by the ratio of coke to ore in the furnace, the iron content of the ore and the volume of blast blown per minute. The first and last of these factors are determined by the blast-furnace operator, who is guided by the regularity of descent of the stock, by the appearance of the combustion zone at the tuyeres, and by the composition and apparent temperature of iron and slag. The operator must keep his furnace in continuous operation, and must keep his ratio of fuel to ore sufficiently high to prevent "freezing" of the furnace.

It is evident that the performance of a furnace depends in great measure upon the operator's opinion as to the minimum amount of coke which may be used. When to the operator variable we add the variables of different ore burden, furnace lines, grades of iron, and uncertainty as to the true analysis and weight of materials going into the furnace, we evidently have a difficult problem in attempting to isolate the effect of various kinds of coke by making use of data obtained at different furnaces.

MEANING OF TERM "COMBUSTIBILITY"

By combustibility of coke, from the standpoint of the blast-furnace is meant the space rate at which oxygen and carbon dioxid disappear in the vicinity of the tuyeres. Assuming a constant volume of blast per minute, the mean combustibility of coke is inversely proportional to the volume of the combustion zone around the tuyeres. In the combustion zone, coke is burned according

to reactions (1) and (2); hence, the limits of the combustion zone are marked by the disappearance of carbon dioxid. The final product of combustion in the blast-furnace is carbon monoxid only; therefore, a given weight of blast burns a definite weight of carbon, irrespective of the combustibility of the coke. A highly combustible coke differs from a coke of low combustibility in completing the above reactions in a shorter distance from the point at which the blast first comes in contact with the fuel—that is, oxygen and carbon dioxid disappear at a shorter distance from the tuyeres, and the entire process takes place in less space. Furnace men believe that the combustibility of a fuel has an important influence on blast-furnace operation.

The term combustibility is often used in discussions of the blast-furnace process without a clear understanding of its meaning. The implication is often made that the weight of carbon burned per minute, under conditions where the volume of blast per minute is constant, increases with the combustibility of the coke. Other writers use the term to describe that variable property of cokes, by virtue of which it is possible to produce a ton of iron with a smaller amount of one coke than of another. In other words, if a blast-furnace is operating smoothly with low coke per ton of metal, and with high tonnage of iron per day, the coke is highly combustible. If mechanical difficulties occur—the furnace will not "take the wind," the blast pressure rises to the danger point, production drops, and the coke ratio has to be increased—then the coke is said to be of "low combustibility."

Howland[3] in a valuable contribution to the literature of the blast-furnace, gives operating data from 26 blast-furnaces. The coke per ton of metal used by these furnaces ranged from 2615 to 1584 pounds. The actual amount of carbon gasified above the tuyeres was shown to vary little, and Howland came to the conclusion that the differences in fuel economy must be due to differences in the combustibility of the fuel. But since he had no means of evaluating the combustibility of the cokes, any other term would have described equally well this unknown variable property of the cokes which affected the fuel economy.

Koppers,[4] using Howland's data as a basis for his calculations, also came to the conclusion that a highly combustible coke

is desirable—again by the arbitrary definition of a highly combustible coke as one which works well in the blast-furnace.

Sutcliffe and Evans,[5] in a recent article, lay great stress on the desirability of a reactive fuel. They cite the critical temperature theory of Johnson, which states that it is necessary to attain in the hearth a certain critical temperature—which Johnson assumes to be the free-running temperature of the slag—and that the difference between this temperature and the temperature of combustion determines the "available heat" for carrying on the reactions in the hearth. This available heat is believed to have a pronounced effect on the economy of the blast-furnace. A more reactive fuel, according to Sutcliffe and Evans, will burn in a zone of smaller volume at the tuyeres, and will give a higher hearth temperature, and hence a greater supply of available heat.

The reasoning of all these investigators is based upon the assumption that the combustion zone extends to a considerable distance vertically and horizontally from the tuyeres; also that variations in the character of the coke markedly affect the extent of this zone. A survey of the work of investigators who have endeavored to explain the chemical reactions taking place in the blast-furnace by analyzing the gases at different levels is of interest in this connection.

EXTENT OF COMBUSTION ZONE IN THE BLAST-FURNACE

WORK OF PREVIOUS INVESTIGATORS

Beginning with Bunsen in 1843, the work of 13 observers[6] at 20 blast-furnaces has been recorded. In 1860, Peter Tunner concluded that combustion at the tuyeres extends in the direction of the air current to a distance of 1.5 feet; the hottest part of the focus, about six inches in extent, being in the middle. The space of combustion extends upward about one foot. Increased pressure, increased blast velocity, or change of tuyere dimensions, only slightly modify the extent of the zone of combustion.

In 1893, Van Vloten[7] published the results of a series of experiments in which gas samples were taken by means of a water-cooled sampling tube, both through the tuyere and through a hole 25 inches above the tuyere. He found that oxygen had disappeared at 24 inches from the tuyere, and carbon dioxid at 40

inches from the tuyere, and that none of the samples taken 25 inches above the tuyere contained any oxygen.

In 1911, Levin and Niedt[8] and in 1913, Norbert Metz[9] conducted an extensive series of experiments in which gas samples were taken during several months at different levels in the furnace. At 1.2 feet above the tuyeres, the former found no oxygen, only a trace of carbon dioxid, and about 43 per cent. of carbon monoxid. Metz had no sampling hole nearer the tuyeres than 5.5 feet. The gases here contained no oxygen, traces of carbon dioxid, and about 42 per cent. carbon monoxid.

The conclusion to be drawn from the work of these investigators is that combustion at the tuyeres is rapid, and that the area of the combustion zone where oxygen and carbon dioxid are present is of small extent compared to the total area of the hearth.

WORK BY THE UNITED STATES BUREAU OF MINES[1]

An investigation of the combustion zone at 13 blast-furnaces has been carried out, gas samples having been secured at various points in the hearth in the plane of the tuyeres. Data have been

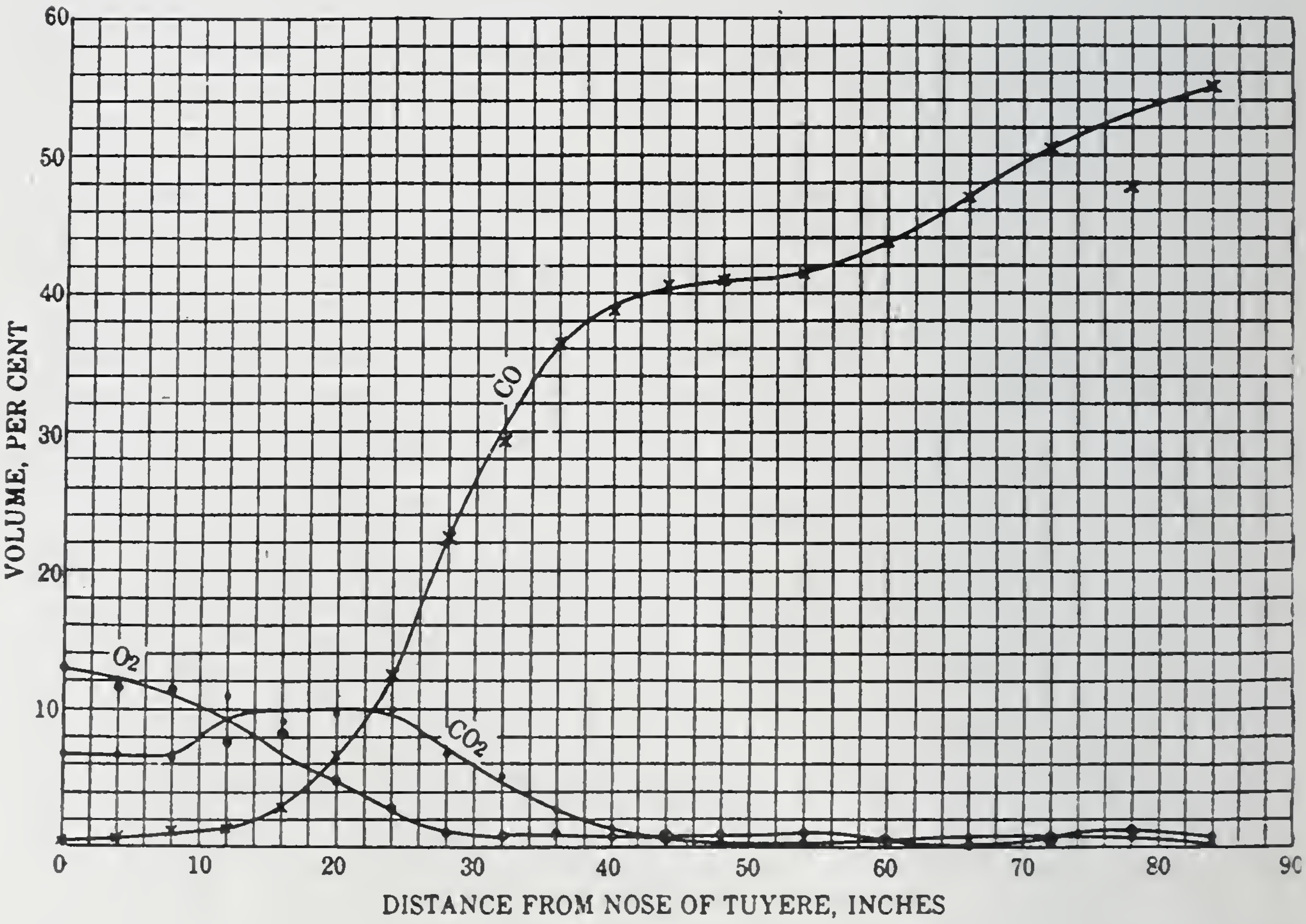

Fig. 1. Combustion of Coke in Blast-Furnace Hearth; Average Data from 10 Furnaces.

secured at six coke blast-furnaces in the Birmingham district, six northern coke furnaces, and one charcoal furnace. Gas samples were secured by means of water-cooled sampling tubes driven into the hearth through the tuyeres.

A curve of the averaged results from 10 furnaces is shown in Fig. 1. These indicate that combustion in the hearth is rapid, the oxygen diminishing to practically zero at 24 to 30 inches from the tuyeres while carbon dioxid disappears at 32 to 40 inches. In other words, the oxygen of the blast has completed its work of gasifying carbon at about three feet from the tuyeres, and the combustion zone occupies about 200 cubic feet, or but one per cent. of the furnace volume.

Differences in the extent of the combustion zone at the several furnaces were found to be a matter of inches only, and bore no apparent relation to the character of the coke. It was *not* shown that furnaces operating on low coke per ton of iron had a combustion zone of smaller extent than the high-coke furnaces.

It was pointed out by Van Vloten[7] that as coke is burned only in a region around the nose of each tuyere, the stock descends rapidly just above the tuyeres, and slowly or not at all at other points on the cross-section of the hearth. According to the analogy used by Van Vloten, the materials flow in the lower part of the furnace as through a number of funnels, one mounted on each tuyere. This irregular descent of the stock, he suggests, may be the cause of hanging and other furnace irregularities.

Royster and Joseph[10] have extended this idea of Van Vloten's and considered how variations in the combustibility of the fuel might change the degree of regularity attained in the descent of the charge. In a modern blast-furnace the hearth is from 16 to 18 feet in diameter, and the axes of Van Vloten's "funnels" are 24 inches from the hearth wall. If a fuel of infinite combustibility were imagined the axes would be moved outward to a point nine inches from the hearth wall, or, in other words, to the nose of the tuyere. By experiments made with models, Royster and Joseph showed the probable course of the descending stock with (1) a fuel of infinite combustibility; (2) a fuel of combustibility that of the average figures of Perrott and Kinney; and (3) a fuel so difficultly combustible that combustion took place across the entire hearth.

Results with (1) and (2) showed that the stock started moving irregularly as high as the stock line itself. A lump of material at the furnace wall moves more rapidly than does a lump several feet in. There is a cone of relatively stationary coke in the center of the hearth and bosh. With the slow-burning coke (3), descent is fairly regular. If, then, regular descent of stock is desirable, an extremely slow-burning coke is needed. However, both (1) and (3) are purely imaginary conditions, and, within the limits found by gas analyses in the hearth combustion zone differences in descent of stock are practically nil.

COMBUSTION TESTS IN EXPERIMENTAL FURNACE

Further work carried out by Sherman and Blizard[11] in an experimental furnace under carefully controlled conditions showed no large differences in the combustibility of various cokes. These experiments were conducted in an experimental furnace of one square foot grate area, which was so fitted that the rate of air supply could be controlled. The cokes were carefully sized, and the depth of the fuel bed and the rate of air supply were maintained the same for all similar tests. The furnace, being brick lined, attained temperatures approaching those of the blast-furnace.

The process of combustion, however, does not go to completion in a furnace of this size; that is, for a fuel bed of these dimensions, the heat losses are so great—particularly the radiation from the surface—that the temperature is not maintained for a sufficient length of gas travel to allow of all the carbon dioxid being reduced to carbon monoxid. The combustibility, therefore, can not be measured by the extent of the combustion zone as in the blast-furnace hearth. The relative combustibilities may be determined in the first few inches above the grate by the rate of disappearance of oxygen; or, for the entire fuel bed, by the percentage of carbon monoxid in the gases leaving the fuel bed. They may also be calculated as a percentage of the maximum attainable combustibility by the expression $\dfrac{CO_2 + CO}{2CO_2 + CO + 2O_2}$ since a gas containing x CO_2, y CO, and z O_2 will give on complete reduc-

tion $2x$ CO, y CO, and $2z$ CO; and the ratio of the carbon present in the gas to the maximum attainable will be as above.

Fig. 2 shows the mean CO and O_2 content of the gases along the path of travel for the four cokes used (when burned at approximately 25 pounds per square foot per hour, using fuel sized

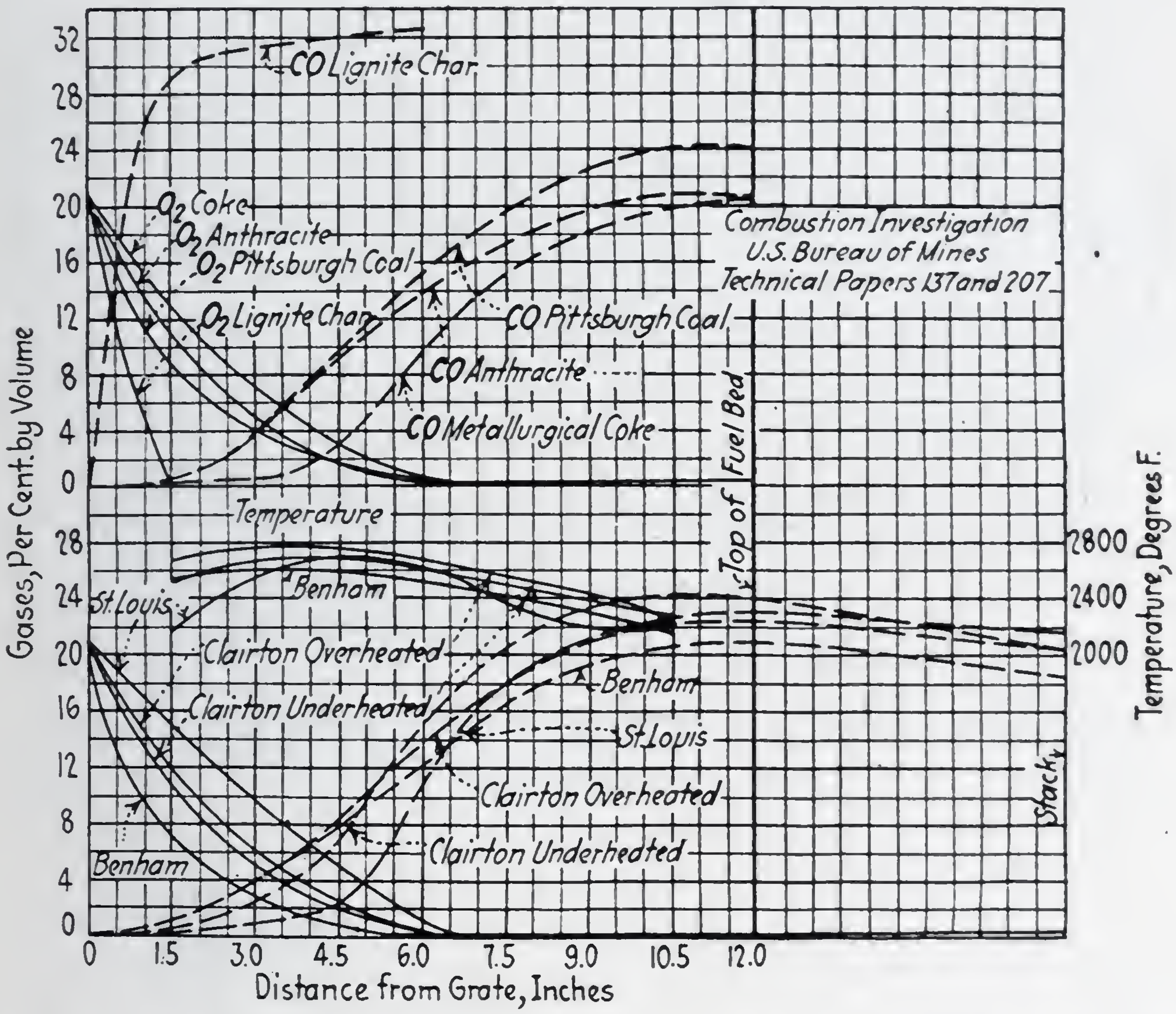

Fig. 2. Mean O_2 and CO Content of Gases and Temperatures in Fuel Bed of Different Fuels.

between 1 and 1.5 inches) and for Pittsburgh coal, anthracite, a metallurgical coke, and lignite char. Differences in combustibility as indicated by these curves are not large, with the exception of the lignite char, which was a particularly reactive type of carbon and was smaller than the cokes, 100 per cent. passing a 0.25-inch screen.

Fig. 3 gives data obtained with a sample of coke made by carbonizing pitch in beehive ovens. With this coke, the rate of com-

bustion, as measured by the rate of disappearance of oxygen, is rapid; but the rate of reduction of CO_2 is much slower than with

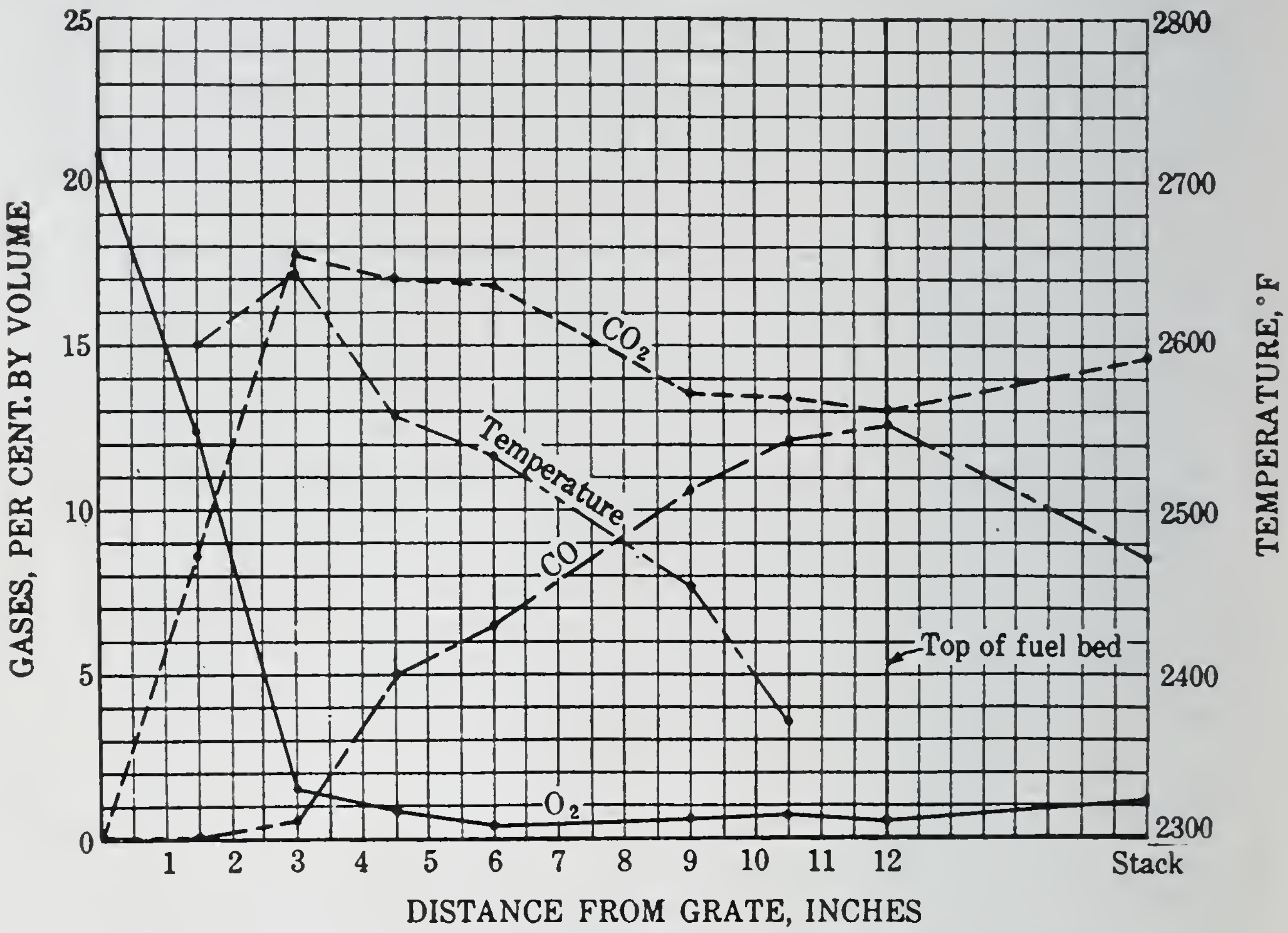

Fig. 3. Combustion in Fuel Bed of Pitch Coke.

the other cokes, the composition of the gases at the top of the fuel bed being 13.0 per cent. CO_2 and 12.6 per cent. CO, as against 8 per cent. CO_2 and 22 per cent. CO with the other cokes.

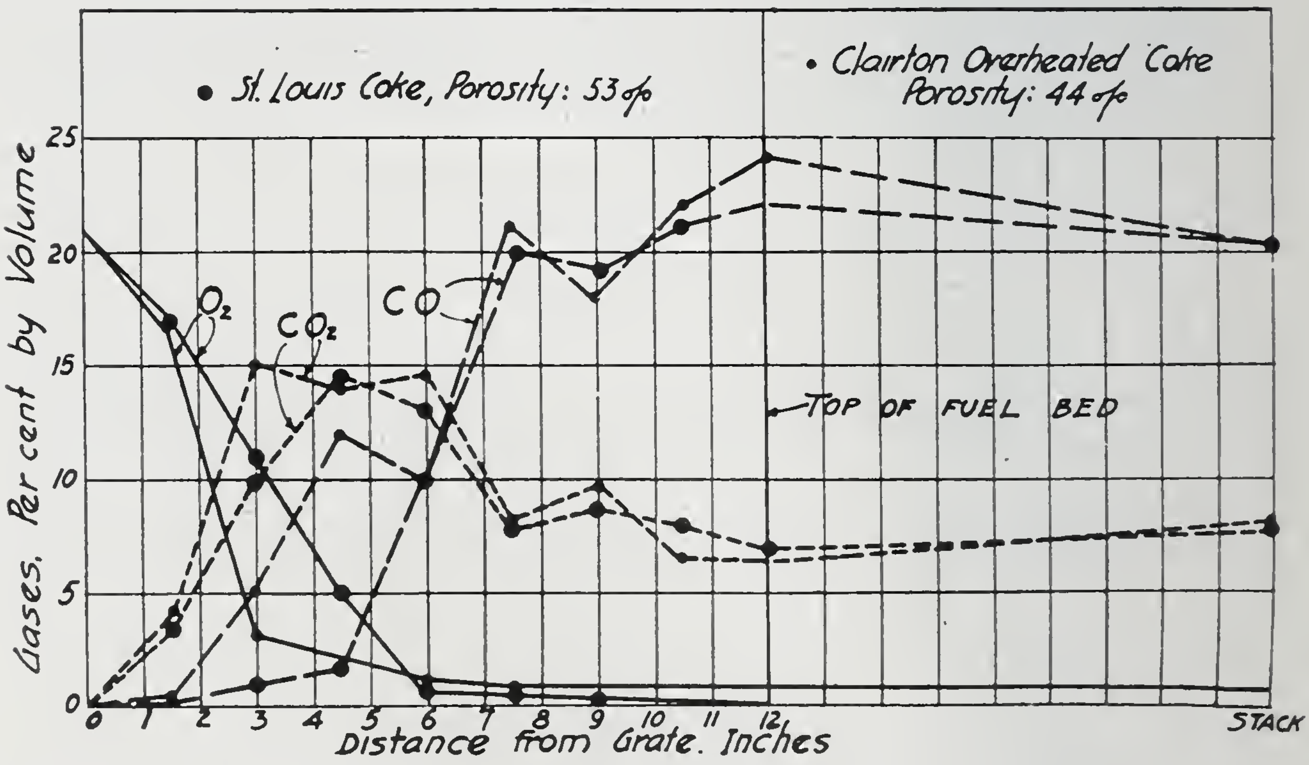

Fig. 4. Effect of Porosity on Combustion in Fuel Bed.

Fig. 4 shows that the rapidity of combustion of two cokes, one with a porosity of 53 per cent. and the other with a porosity of 44 per cent., was practically identical.

Fig. 5 shows the effect of the size of coke on the rapidity of combustion. It compares Benham coke crushed to two sizes—1.5 to 1 inch and 0.25 to 0.125 inch, respectively. It will be seen that there is considerable difference in the curves for the two

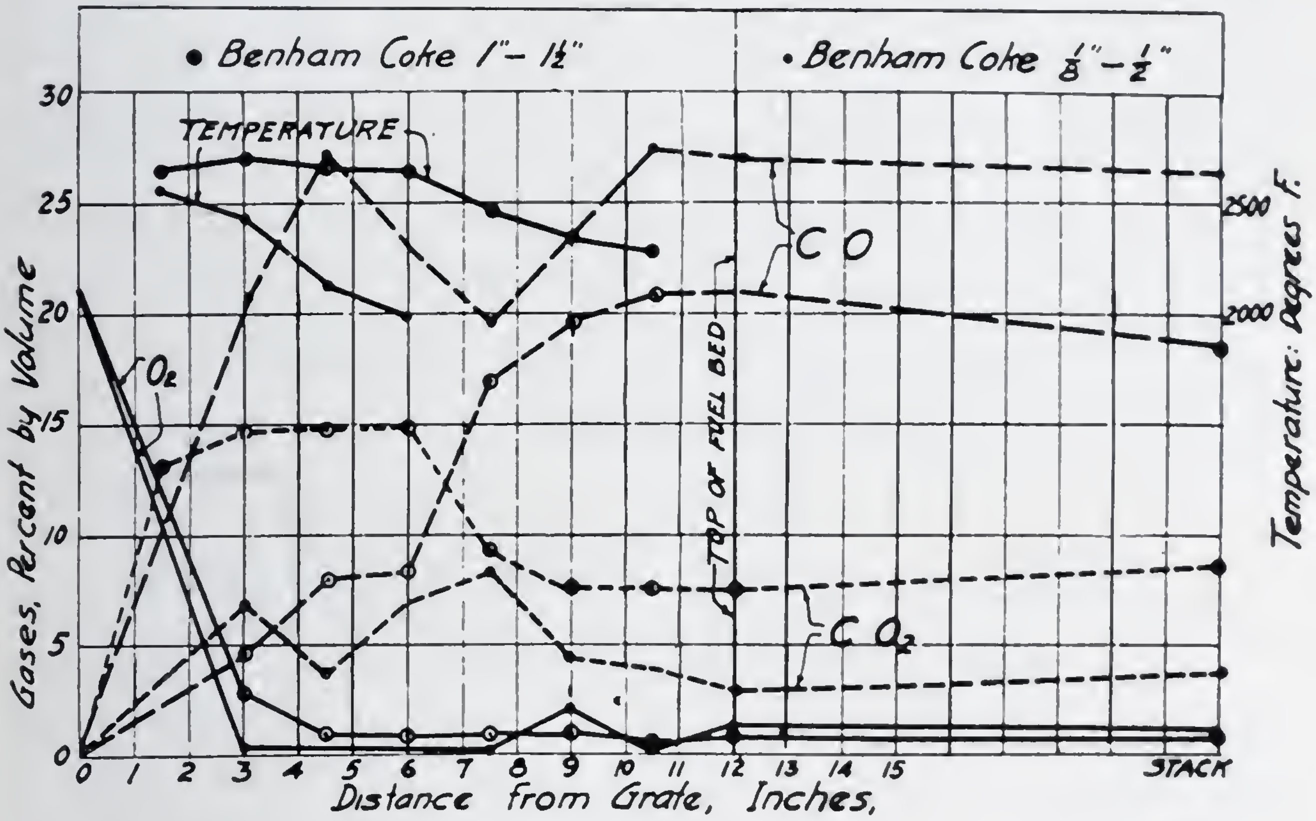

Fig. 5. Effect of Size of Fuel on Combustion in Fuel Bed.

sizes. The oxygen has disappeared at three inches from the grate in the smaller size, and not until 4.5 to 6 inches in the larger size. The carbon dioxid is but three per cent. and the carbon monoxid 27 per cent. at the top of the fuel bed, compared with eight per cent. and 22 per cent. respectively, for the larger size. The temperature falls much more rapidly with the smaller sizes of coke.

The work of Sherman and Blizard previously mentioned has shown differences in the combustibility of different cokes; but no apparent relation between combustibility and other properties of the cokes has as yet been discovered, and the relation to blast-furnace operation is not clear. It is doubtful whether the differences observed in the four cokes shown in Fig. 2 are of sufficient magnitude to be noticeable in blast-furnace operation. The curve for the pitch coke is considerably different and it is conceivable

that the difference in combustibility is sufficient to increase the extent of combustion zone in blast-furnace operation. No blast-furnace running on straight pitch coke has been investigated. The combustion zone at a charcoal furnace, which at times used 25 per cent. pitch coke, was investigated and not found to vary appreciably when the pitch coke was added to the burden. Tests should be made in the experimental furnace mentioned, with Connellsville beehive coke, which shows a low reactivity with carbon dioxid and according to laboratory tube tests is about equal in reactivity to the pitch coke. Investigation at blast-furnaces using Connellsville beehive coke failed to show a combustion zone of greater extent than at furnaces employing more "reactive" by-product cokes. It seems probable that at the high temperature of the blast-furnace combustion zone, oxygen and carbon dioxid are oxidizing agents of equal activity, and that the character of the carbonaceous material oxidized plays a lesser rôle than at lower temperatures.

OXIDATION OR "SOLUTION" BY CARBON DIOXID

Since the time of Bell it has been realized that not all the carbon charged as fuel reaches the tuyeres to be burned by the oxygen of the blast. A variable amount is oxidized above the tuyeres or in the hearth by oxygen from other sources. This oxidation may take place as direct reduction of iron oxid and oxids of manganese, phosphorus and silicon, or as oxidation of carbon by carbon dioxid—the so-called "solution loss" of blast-furnace parlance.

According to Gruner,[12] the most efficient operation is obtained when all of the ore is reduced by "indirect reduction"—that is, by carbon monoxid—and thus all of the carbon charged (with the exception of that required to carburize the iron and reduce oxids of silicon, manganese, and phosphorus) is burned at the tuyeres. This condition of operation has been referred to as Gruner's "ideal working."

Oxidation of carbon by solid oxids or by carbon dioxid in the stack is evidenced by a decreasing percentage of nitrogen in the stack gases. Dry air burns pure carbon according to the equation, combustion, therefore, consist of

$2C + O_2 + 3.78\ N_2 = 2CO + 3.78\ N_2$. The resulting gases of

$$\frac{2}{5.78} = 34.6 \text{ per cent. CO, and } \frac{3.78}{5.78} = 65.4 \text{ per cent. } N_2.$$

Factors which diminish the percentage of nitrogen in the stack gas are:

1. Direct reduction:

$$FeO + C = Fe + CO$$
$$SiO_2 + 2C = Si + 2CO, \text{ etc.}$$

2. Oxidation of carbon by CO_2 formed above the tuyeres:

a $FeO + CO = Fe + CO_2$
b $CO_2 + C = 2CO$

3. Oxidation of carbon by water vapor:

$$H_2O + C = CO + H_2$$

4. Decomposition of limestone:

$$CaCO_3 = CaO + CO_2$$

5. Evolution of volatile matter from fuel.

The first two factors account for the greater part of the dilution of nitrogen. The stack gas of the modern American blast-furnace contains from 59 to 56 per cent. of nitrogen, indicating that the amount of carbon oxidized above the tuyeres is 20 to 30 per cent. of the total carbon charged as coke (assuming two per cent. of hydrogen). It is impossible to distinguish between "direct reduction" and "solution loss" without making certain assumptions of doubtful validity.

Gruner's ideal working has for many years been the orthodox view as to the condition of maximum efficiency of operation, and a coke very resistant to oxidation by carbon dioxid has been considered desirable. Howland, however, pointed out (1) that none of the 26 furnaces he examined worked according to this so-called ideal method; (2) that he knew of no blast-furnace anywhere in which 100 per cent. of the gasified carbon was gasified at the tuyeres; and (3) that he did not consider such a condition desirable. In a discussion of Howland's paper, J. W. Richards noted that the amounts of carbon gasified above the tuyeres (as

distinguished from percentages of the total carbon gasified) were relatively constant for the 26 furnaces, and concluded that solution or gasification of fuel above the tuyeres is independent of fuel consumption, practically constant in amount per ton of iron made, and does not condition or determine the fuel efficiency of the furnace in usual furnace practice.

Koppers believed it desirable to use a coke which is readily oxidized by carbon dioxid. By reason of the endothermic nature of the reaction, the shaft is kept cooler, and the reducing and melting zones separate; and, in addition, the coke is kept cooler than its surroundings and in its original highly combustible state. This reactive fuel may be made, according to Koppers, by carbonizing at temperatures between 550 and 800 degrees C. If one takes into consideration the length of time coke is in the furnace before reaching the tuyeres· the rapidity with which gases come to temperature equilibrium with solids, and the high temperatures to which the coke is subjected before reaching the combustion zone, considerable difficulty is experienced in following the reasoning of Koppers's assertion that the fuel will still be low-temperature coke when it reaches the tuyeres.

Sutcliffe and Evans believe that a high "solubility factor" in coke is a most desirable asset in securing low fuel consumption. They base their reasoning on (1) Johnson's critical temperature theory; (2) the high efficiency of charcoal furnaces; (3) Howland's assertion that "low coke consumption goes hand in hand with low wind;" and (4) the belief that direct reduction requires less carbon per unit of iron than does indirect reduction. These points may be discussed as follows:

1. It has been shown that the argument for a "reactive" fuel, based on Johnson's critical temperature theory, bears considerably less weight when it is realized that variations in the character of the fuel change the extent of the combustion zone by a matter of inches only.

2. Stack-gas analyses from charcoal furnaces do not indicate a greater amount of carbon gasified above the tuyeres than in coke furnaces.

3. Inspection of Howlands paper shows that he concluded that the amount of wind per pound of coke was practically constant for the 26 furnaces examined, and that the above quoted

statement referred merely to the amount of wind going through the furnace per minute. For a given tonnage of iron, this figure obviously depends directly upon the amount of coke used per ton of iron, even though an identical coke were used in all cases.

4. Since direct reduction takes place in regions of high temperature where any carbon dioxid formed is immediately reduced to carbon monoxid, it is obvious that direct reduction requires the same amount of carbon per unit of iron as indirect reduction. The increased fuel economy of direct reduction depends upon the amount of the carbon monoxid that undergoes further oxidation by iron ore in the stack, a factor the value of which it is difficult to predict.

To our knowledge, no data have as yet been brought forward which show a larger amount of carbon gasified above the tuyeres per unit of iron with the so-called reactive fuels.

A laboratory test for determining the relative reactivity of metallurgical cokes with carbon dioxid has been devised by one of the writers[13] of this paper. Carbon dioxid is passed for one hour at a rate of one liter per minute, through a two-inch layer of six- to eight-mesh coke contained in a quartz tube one inch in internal diameter. The temperature of the coke is maintained at 1000 degrees C. throughout the test by means of an electrical resistance furnace. The result is reported as grams of carbon oxidized during the test. A comparison of test results with actual operating data is shown in Table I.

Data show that while the loss by carbon dioxid at 1000 degrees C. varies considerably for the different fuels, no relation is apparent between this value and the percentage of carbon gasified above the tuyeres, or the weight of carbon gasified per unit weight of iron. The most noticeable relation is the constancy of the amount of carbon gasified above the tuyeres per unit weight of iron for furnaces operating on similar kind of ore. The northern furnaces using lake ore containing 51 per cent. Fe show about 18 pounds of carbon gasified above the tuyeres per pound of iron. The Alabama furnaces using ore of considerably larger size, and containing 37 per cent. Fe, show about 26 pounds of carbon gasified above the tuyeres per pound of iron. Charcoal furnaces show a lower amount of carbon gasified above the tuyeres per

TABLE I. RELATIVE REACTIVITY OF COKE WITH CARBON DIOXID

Furnace	Type of coke-oven	Coal: State	Coal: Seam	Tons of iron per day	Coke per ton of iron	Carbon gasified above tuyeres: Per 100 lb. carbon	Carbon gasified above tuyeres: Per 100 lb. iron	True density of coke	Apparent density	Porosity	Loss by CO_2 on standard test: Grams	Loss by CO_2 on standard test: Relative
1	BH	Pa.	Pittsburgh	220[a]	2800	25	26.5	1.89	1.02	46	0.7	10
2	BH	Ala.	Pratt	322	2807	23.5	26	2.13	1.15	46	0.9	13
3	BH	Pa.	Pittsburgh	580	1960	23	17	1.90	0.98	48	0.9	13
4	SS	Ala.	Brookwood and Mildale	258	3160	22	26	2.00	0.99	51	1.1	16
5	SS	Ala.	Mary Lee	260	2800	28	23	1.96	1.00	49	1.1	16
6	SS	Ala.	Mary Lee	356	3345	23	29	1.92	1.05	45	1.1	16
7	K	Ala.	Pratt	418[d]	1900	22	29[e]	2.04	1.14	44	1.2	17
8	K	Ala.	Pratt	476	2750	22	24	2.01	1.13	44	1.2	17
9	K	Pa.	Pittsburgh	512	1960	24	18	1.90	0.98	48	1.3	19
10	K	Pa.	Pittsburgh	525	2100	22	18	1.99	1.04	48	1.5	21
11	R	Ill.	No. 7	515	1770	27	17.5	1.84	0.87	53	3.0	43
Charcoal Furnace[b]	..	Herrang Sweden	Charcoal[c]	...	1600	21	12	....	....	..	7.0[c]	100
Charcoal Furnace	..	Ala.	Charcoal	50	2080	22	15	....	....	..	7.0	100

[a] Spiegeleisen.
[b] J. W. Richards, "Metallurgical Calculations", Edition 2, 1916, p. 246.
[c] Average of several samples of wood charcoal made in the United States.
[d] Forty-five per cent. scrap.
[e] On basis of iron produced from ore, exclusive of scrap.

pound of iron than do the northern furnaces operating on coke, although the reactivity of charcoal with CO_2 at 1000 degrees C. is 10 times that of Connellsville coke.

From these data and the data of Howland it does not appear that the reactivity of the fuel greatly influences the amount of carbon gasified above the tuyeres. The character of the ore plays an important part. Ore charged in large pieces, as at the Alabama furnaces, probably reaches a lower zone in the furnace before being completely reduced than do the finer lake ores. Reduction here may take place either by carbon or by carbon monoxid, but at the high temperatures near the hearth the result is the same, because any carbon dioxid formed is immediately reduced.

COKE SPECIFICATIONS

1. The discussion shows that, aside from chemical analysis, we are not at present in a position to write specifications for metallurgical coke. If the properties of cokes being used successfully in this country be taken as criteria we might say that any coke having an ash content of less than 13 per cent., sulphur less than 1.25 per cent., true specific gravity over 1.80, porosity less than 55 per cent., and a shatter test over 40 per cent., will be satisfactory for blast-furnace use. This does not mean that cokes falling outside of the limiting physical properties will necessarily be unsatisfactory.

2. In testing coke the following determinations should be made:

a. Percentage of various sizes as determined by screen test.

b. Complete chemical analysis, including analysis of ash.

c. Determination of true and apparent specific gravity, porosity and weight per cubic foot of loose coke as delivered to the furnace.

d. Shatter test (three to five duplicate determinations).

e. Relative rate of oxidation by carbon dioxid, using standard conditions similar to those described in this paper.

f. Relative combustibility in an experimental furnace under carefully controlled conditions (the furnace described in this paper has given satisfactory results).

The meaning of *a, c, d, e,* and *f* in terms of blast-furnace operation is not definitely known. The importance of the properties measured by *e* and *f* as regards the fuel economy of the furnace is open to doubt, but further data should be secured. It is reasonably certain that these tests measure all the properties of coke which can affect blast-furnace operation.

CONCLUSION

1. Exploration of the hearth combustion zone of 13 blast-furnaces, using fuels ranging from charcoal to Connellsville bee-hive coke, has shown only small differences in the extent of this zone; and these bear no determinable relation to the properties of the coke or to the fuel economy of the furnace. Until contradictory experimental evidence is secured, it must be concluded that other factors than the combustibility of coke at the tuyeres are responsible for the large differences reported in blast-furnace operation with different cokes.

2. The reactivity of cokes with carbon dioxid has been shown to vary considerably at temperatures below 1200 degrees C., but under actual blast-furnace operation the amount of carbon gasified above the tuyeres per ton of iron is practically constant for a given kind of ore burden, and is independent of the character of the coke.

3. From the data so far available it seems that too much stress has been placed on the importance of combustibility of cokes and their reactivity with carbon dioxid, and that excellent operating records may be made with any coke of suitable chemical composition, size, mechanical strength and sufficiently low apparent density to keep the constituents of the burden well separated and permit of easy passage of the gases.

4. Further tests are needed at a blast-furnace under carefully controlled conditions, and it is hoped that the work at the experimenal blast-furnace of the United States Bureau of Mines station at Minneapolis will throw additional light on the subject.

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DISCUSSION

Dr. John S. Unger:* We are very much interested in the question of what constitutes good coke for blast-furnace use, and have made a number of experiments in which we tried to determine some of the properties required.

In one set of experiments we tried to determine what kind of coke would burn the most rapidly, as we believe more iron can be produced with a rapid-burning coke, than with one which burns at a slower rate.

In these experiments, we used a small brick-lined cylindrical shaft furnace about six feet high with a 10-inch diameter vertical opening at the center. Cold blast was supplied at the bottom and, when in operation, the furnace was kept full of coke to the top. We soon found careful, close sizing of the coke to be essential. To secure results which would approximately check on the same sample, we had to screen through a 1.5-inch hole and catch on a one-inch hole. We began our work with samples of 100 pounds burning over a period of three hours but had to change to 300-pound samples burning for eight hours, to eliminate the variables in the experiment.

Samples from the same carload had to be carefully selected, as what might be called black ends were, on close inspection, found to be hard coke stained black by smoke or tarry matter. To check doubtful lumps, a rough specific-gravity test was made by dropping the lump into a bucket of water. From the same car of coke, we found the black ends contained about four per cent. volatile matter, and the hard coke about 1.25 per cent.

In burning the same kinds of coke, whether hard or black ends, and comparing them with similar kinds of coke made by a different method our results showed a difference in the burning rate of about 10 per cent. Since close sizing and elimination of black ends in blast-furnace coke is impracticable, it is apparent that a study should be made of the methods of producing a furnace coke which will burn faster than another coke in a blast-furnace even though it carries the above variables.

*Manager, Research Bureau, Carnegie Steel Co., Pittsburgh.

Mr. George W. Vreeland:* The combustibility of coke in a blast-furnace has been under discussion to a considerable extent the past few years and I will have to agree with the speaker that we do not know much about the combustion of coke, or what is good or poor coke in a blast-furnace without actually charging the coke and then watching results, which is the final analysis in practically every case.

One statement made by Mr. Perrott I would like to speak about, and that is that we could derive a considerable amount of data if we had furnaces under the same operating conditions. I have on many occasions changed coke with all the other conditions constant, and found that the tonnage of the furnaces will increase or decrease as the case may be; also, the quantity of coke required to make a ton of iron will increase or decrease.

After operating with these varieties of coke we can say almost exactly what the furnace will do under varying coke conditions. The cokes are all from the Connellsville region and made within a relatively short distance of each other. The chemical analysis shows only a slight variation—possibly 1 per cent. in carbon and 0.2 per cent. in sulphur, with volatile the same; but we have a variation in driving or amount of coke consumed per 24 hours with constant quantity of air. The increase or decrease in tonnage under constant operating conditions must be due to some cause and at present I cannot give an exact reason for this increased quantity of coke consumed per unit of time, but it does look as if a fast or slow driving furnace does to a considerable extent depend on the rate at which the coke can be burned or consumed in the lower zone of the furnace.

Hanging and slipping and so-called mechanical troubles do affect the chemical and metallurgical operations, but due to improved design and operations these troubles are almost eliminated.

The method of filling a furnace has considerable influence on mechanical and metallurgical operation and with all the work that has been done on this one phase of operation we do not know exactly how to charge a furnace especially under varying conditions of raw material.

*Superintendent of Blast Furnaces, Carnegie Steel Co., Mingo Junction, Ohio.

Coke is the life blood of a blast-furnace and I hope the day will come when we will know enough about it to say what makes good coke, and also how to specify it.

MR. H. J. ROSE:* The gentlemen who have just spoken have emphasized the importance of "fast driving coke". Blast-furnace men agree that there is a great difference between cokes in this respect. They want a "fast driving coke" and believe that this characteristic is largely due to its reactivity or combustibility.

In the laboratory work on coke combustibility which has been described this evening, two kinds of tests were run. The author has discussed the results of a series of tests made at a very low air rate, in which the gases in the combustion zone at different distances from the grate were analyzed Some important differences were found in the combustion zone, but the final products of combustion were about the same for each coke. Other tests were made, however, which have not been discussed or illustrated. In these tests, air was passed through the cokes at varying rates, the highest rate approaching blast-furnace conditions. The results show that the combustion efficiency of one coke increased as blast-furnace rates were approached, while two cokes decreased in efficiency. The final difference amounted to 10 per cent. increased combustion efficiency in favor of the coke which blast-furnace men have found to be the best. The speaker hopes to do a large amount of work on a similar laboratory test during the coming year.

The analyses of gases from the combustion zone of blast-furnaces were confined to samples taken directly in front of the tuyeres. The authors have done a great deal of work at no little expense to get these results, and we are surely appreciative of this investigation. However, we need to have an exploration of the entire combustion zone carried out in a similar way. This is admittedly a difficult, and in fact a dangerous, piece of work, but it is one that is needed.

MR. G. W. HUGHES:† I would like to ask if we have any data or conclusions on the effect of using small coke in the blast-furnace. I refer to the pea and nut size—coke that will pass

*Coal Division, The Koppers Co., Pittsburgh.
†Superintendent of Blast Furnaces, Pittsburgh Steel Co., Monessen, Pa.

a one-inch screen. Some furnace plants are equipped for screening the breeze and small-size coke out and then rescreen this material and use the small-size coke in the furnace. Others dispose of the small coke in various ways and do not use it in the blast-furnace.

The point I wish to bring out is this—is it good practice, or does it pay, to use pea and nut size coke in a blast-furnace?

Mr. G. St. J. Perrott: In reply to the question of Mr. Hughes, we have no original data as to the value of small coke in blast-furnace operation. The data which we have collected from a number of different furnaces contain so many variable besides the size of the coke that it is practically impossible to isolate the effect of this factor Here again, data are needed from one furnace at which the size of the coke is varied and all other conditions of operation kept constant. I know of a furnace plant in the Birmingham district and one in this district where domestic size coke has been used for a time with considerable success. On the other hand, another plant in this district attributes most of the mechanical difficulties (slipping and hanging) which occur in several of their furnaces to the fact that these furnaces are using smaller coke than the other furnaces in the plant.

In answer to Mr. Rose, I believe that the differences in combustion efficiency at the higher rates in the experimental furnace were probably due to differences in the ash content of the cokes. There is always a small layer of ash and partially burned coke on the grate and at the higher rates it is more difficult to keep the grate clean. Obviously this difficulty increases as the ash content of the coke increases. The Benham coke which showed increased efficiency at the higher rates contained a lower percentage of ash than the other cokes tested. In regard to the work at the blast-furnaces, I agree with Mr. Rose that samples of gas should be taken in planes above the tuyeres. Such work is now in progress in the Birmingham district.

I should like to ask Dr. Unger in connection with his experimental furnace, in what terms he measures combustibility. Does he mean that in a furnace containing no iron ore,

a given amount of wind will burn more of one coke than of another?

Dr. John S. Unger: Yes, 10 per cent. more under exactly the same conditions.

Mr. G. St. J. Perrott: Is it a slagging furnace?

Dr. John S. Unger: No, it is cleaned out after each period of fire.

Mr. G. St. J. Perrott: It is impossible to burn more of one kind of carbon than another with a given amount of wind providing combustion is complete to carbon monoxid. Do you know the composition of the gases coming off the fuel bed?

Dr. John S. Unger: No, we are not interested in that.

Mr. G. St. J. Perrott: The gases are undoubtedly a mixture of CO and CO_2. If Dr. Unger employed low rates of combustion the composition of these gases and hence the amount of carbon burned might vary considerably with the character of the coke. This is due to the fact that, at temperatures around 1000 degrees C., the rate of oxidation of carbon by CO_2 varies considerably with the character of the coke. At the higher temperatures attained with rapid combustion, this reaction rate is much the same for all cokes. The ash content of the cokes would influence the amount burned in a furnace of this type because its accumulation at the bottom would cause a diminishing height of fuel bed as the test proceeded.

Mr. H. J. Rose: Referring to the matter of small coke I recently had the pleasure of attending a meeting of the Eastern States Blast Furnace and Coke Oven Association at which the subject of the evening was coke size. Almost everyone agreed that a large and uniform coke was wanted. In a discussion of the value of very small sizes, Mr. C. A. Meissner, Chairman of the Coke Committee of the United States Steel Corporation, stated that furnaces had been experimentally operated on very carefully

sized nut and pea coke with results that exceeded expectations. I don't think that any furnace in the country is operating on such small sizes, however.

Mr. George W. Vreeland: I think that possibly there is a misunderstanding regarding the statement made by Mr. Meissner some time ago that a furnace made a successful run on 100 per cent. fine coke. The furnace he talked about did very successful work on domestic coke; but, on 100 per cent., more or less trouble was encountered and I think that was Mr. Meissner's viewpoint.

From our operations with a certain percentage of small domestic coke (0.75 inch to 1.5 inches) I believe the most successful operations have been to charge this class of coke separately and not mix it with the large coke, thereby keeping the percentage of voids in large and small about the same, where if the small coke is mixed with large coke the void percentage is cut down.

Mr. R. H. Schaller:* In my opinion, it is very important to have coke of uniform size. I do not believe it is profitable to use very small coke along with the larger sizes. If we cannot have all our coke pass a two-inch or three-inch screen, I believe we can get satisfactory operating results with coke the size of an egg or a walnut if it is uniform in size. The Bethlehem Steel Company put its furnace C on domestic coke for a short period the latter part of May, but changed again to the regular coke.

*Assistant Superintendent, Pittsburgh By-Product Coke Plant, Jones & Laughlin Steel Corporation, Pittsburgh.

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BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Old Colony Club, William Penn Hotel, Tuesday, January 16th, at 4:45 P. M., President H. D. James presiding, Messrs. Knowles, Crabtree, Hunter, Danforth, Hawley, Hobbs, Khuen, Moore, Weldin and the Secretary being present.

The Minutes of the last meeting were approved without reading.

Applications for membership received from the following gentlemen, having been previously published to the Society in accordance with the action of the Board, were elected to membership:

MEMBER

Cooper, Howell C.

ASSOCIATE MEMBER

Thomson, Joseph Carl

JUNIOR

Chappell, Thomas V.

Applications for membership were received from the following gentlemen and were graded by the Membership Committee as follows:

MEMBERS

Burgess, Charles Calvin
McConnell, Charles H.
Peirce, W. Bradford

ASSOCIATE MEMBER

Halbert, Charles Raymond

STUDENT JUNIOR

Wishoski, Ignatius Stanley

Letter was received from Mr. W. C. Shrom asking to be reinstated to membership. After discussion Secretary was requested to advise Mr. Shrom that his name had been placed on the Society rolls.

Resignations were received from the following gentlemen and ordered accepted:

Bathgate, O. H.	Porter, H. C.
Crew, J. A.	Robinson, Wm. R.
Muir, John J.	Thomas, J. Fred
McKee, W. J.	Tweedy, A. W.
Oseroff, D. M.	Coon, Mortimer F.

The Report of the Secretary showing the financial condition of the Society at the close of business December 31, having been audited by the Finance Committee, was approved.

COMMITTEE REPORTS

The Secretary reported in the absence of Mr. Ladd, Chairman of the Entertainment Committee, stating that arrangements were about completed for the Annual Banquet and that reservations up to the present time indicated that we were going to have an exceptionally large banquet.

Mr. Fohl, Chairman of the House Committee, reported an evening attendance in the Society Rooms of 134 for the month of December.

In accordance with the suggestion of the Board at its last meeting, the House Committee placed a box in the Society's room to receive donations for Christmas funds to be given the employees in the hotel. A total of $21.50 was received. It was found that even by the closest economy we needed a total of $39.50, and it was, therefore, necessary to take the difference from the petty cash held by the Secretary. A detailed statement of these donations was made up.

In connection with the work of the House Committee during the coming year, this Committee respectfully suggests that a bridge tournament be held some time next spring.

It was found necessary owing to the increased attendance in the rooms during the noon hour to purchase two new hatracks, and the Committee has authorized the Secretary to make the purchase.

The Membership Committee held one meeting, at which the various applications received were gone over and assignment made to the various grades of membership.

There was one reinstatement, and the recommendation was made that 10 resignations be accepted.

Meeting adjourned at 5:30 P. M.

K. F. Treschow, *Chairman.*

CIVIL SECTION

The Annual Meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, January 9th, at 8:15 P. M., Vice Chairman H. R. Thayer presiding, 101 members and visitors being present.

The Minutes of the last Annual Meeting were read and approved.

The Annual Report of the Section was read by the Secretary.

The report of the Nominating Committee was read by Mr. George H. Danforth, Chairman, as follows:

"Officers and Members of the Civil Section,
Engineers' Society of Western Pennsylvania:

Dear Sirs:

Your Nominating Committee has appointed the following nominees for the several officers of the Section for the ensuing year:

Chairman..........H. R. Thayer
Vice Chairman..........B. A. Ludgate
Directors..........P. W. Price, E. V. Braden, C. C. Dornbush, J. F. Haldeman, J. M. Rice

Respectfully submitted,

G. H. Danforth, Chairman,
L. P. Blum,
C. B. Stanton,
Nominating Committee."

On motion the nominations were closed and the Secretary instructed to cast a unanimous ballot in favor of the officers named, and they were, therefore, declared elected.

There being no further business, the meeting adjourned, and the regular bi-monthly meeting was called to order by Chairman-elect H. R. Thayer.

The Minutes of the last bi-monthly meeting, held November 7th, were read and approved.

No further business coming before the Section, the paper of the evening, on "Concrete Pipe—Plain and Reinforced," was presented by Mr. Joseph S. Lambie, Associate Professor, Civil Engineering, University of Pittsburgh, Pittsburgh, Pa.

The ensuing discussion was participated in by: J. M. Dilley, Field Engr., Portland Cement Association; J. S. Martin, Structural Engr., Philadelphia Company; C. F. Buente, Cons. Engr. & Secy., Concrete Products Co.; B. A. Ludgate, Asst. Engr., P. & L. E. R. R.; C. G. Dunnells, Head, Dept. Building Construction, Carnegie Inst. of Technology; F. M. McCullough, Professor, Civil Engineering, Carnegie Inst. of Technology; J. M. Rice, Consulting Civil Engineer; P. J. Freeman, Chf. Engr., Tests, Pittsburgh Testing Laboratory; J. H. Smith, Professor, Civil Engineering, University of Pittsburgh; H. R. Thayer, Markhart-Thayer Engineering Co.; and the author.

On motion the meeting adjourned at 10:35 P. M.

K. F. Treschow, *Secretary.*

ANNUAL MEETING

The Forty-third Annual Meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, January 16th, at 8:07 P. M., President Henry D. James presiding, 89 members and visitors being present.

The Minutes of the last Annual Meeting, held January 16th, were read and approved.

The Annual Report of the Board of Direction, which included the reports of the Standing and Special Committees, the Sections and the Treasurer, was read, as follows:

REPORT OF BOARD OF DIRECTION

The Board of Direction of the Society held ten regular and one special meetings during the year, at which routine business of the Society was transacted.

During the year there were nine regular and the Annual Meeting of the Society. The total attendance was 764, the average being 76. The maximum attendance was 185, at the September meeting, and the minimum 16, at the February meeting. The average number participating in the discussion of the papers was six.

At the close of the year the membership of the Society was as follows:

Honorary Members	1
Members	1120
Associate Members	89
Associates	30
Juniors	78
Student Juniors	2
	1320
Dropped	37
Resignations	47
Removed by death	9
	93
Accessions	107

Respectfully submitted,

K. F. Treschow, *Secretary.*

REPORT OF HOUSE COMMITTEE

To Board of Direction,
Engineers' Society of Western Pennsylvania:

Dear Sirs:

The House Committee beg to report on the work done during the year 1922 as follows:

During the year the furniture in the Club Room was gone over and refinished where it was needed, which work was done gratis by the Jos. Horne Co. Four additional hatracks were purchased owing to the increased use of the Club Room during the noon hours.

The large table and twelve chairs used in the Union Arcade Bldg. were sold to the National Tube Co. for $100.00, and the two green rugs used in the offices for $40.00.

An estimate was given the A. I. E. E. and American Society for Steel Treating on the cost of holding meetings, using our auditorium, the clerical and secretarial work to be done by the Society. These estimates did not meet with the approval of either Society. We are continuing to assist these societies by securing rooms for their meetings.

The usual Chess Tournament was held, Mr. A. Stucki winning the prize in the first series and Mr. F. K. Howell the one in the second series. The Chairman of the House Committee purchased the cup for the first series and Mr. Stucki the one for the second series.

The Committee has recommended that a Bridge Tournament be held in the spring, to be followed by an evening of bridge, at which the ladies would be invited. The recommendation received the approval of the Board of Direction.

The first of the year an arrangement was made with the William Penn Hotel whereby three tables have been reserved in the Cafeteria for the use of the Members of the Society and their friends from 12 to 2 o'clock, coffee being served at the table free of charge. This arrangement has proved very successful and we have had an average attendance of 60 or 70 during the past two or three months, and it is believed that more members will make use of this privilege in the future.

It has been very gratifying to note the increased use of our rooms both in the evening and during the noon hour. We had an evening attendance of 1496 this year, as against 561 last year.

Respectfully submitted,

W. E. Fohl, *Chairman.*

REPORT OF PUBLICATION COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania:

Dear Sirs:

During the year two meetings of the Committee were held, with an average attendance of six.

Papers presented at the general Society meetings	10
Papers read at various Sections	21

Two meetings of the Practicing Engineers' Section were held to discuss the business of the Section, one paper being presented at one of these meetings. Sixteen of the above papers presented have been published in the Proceedings of the Society or will appear in later issues.

The publication of the Proceedings is now up to date, and if nothing unforeseen occurs future issues will be published on time.

Respectfully submitted,

FREDERIC CRABTREE, *Chairman.*

REPORT OF ASSOCIATED ENGINEERING SOCIETIES OF PTTSBURGH

To the Board of Direction,

Engineers' Society of Western Pennsylvania:

Dear Sirs:

Meeting held September 29th to consider resolution of the Civic Affairs Committee recommending that the Judges of Court of Common Pleas give careful consideration to the appointment of a successor of J. G. Chalfant, deceased, and the propriety of advancing in rank those who have shown their ability to handle affairs of the office. Resolution approved.

Meeting held September 18th to pass upon the recommendation of the Civic Affairs Committee in regard to program for the purchase of new or enlarging of old Playgrounds. Also in regard to a meeting to be arranged at which a speaker from the Department of City Plan of Pittsburgh be asked to speak on the Proposed Zoning Ordinance. The action of the Civic Affairs Committee was approved in both cases.

Meeting held March 17th in regard to awarding of contract by County Commissioners for the California Bridge at Jacks Run to architects, it being suggested that this should be in the hands of an engineer. Recommendation was made that a Committee call upon Council to take this matter up with them.

The Associated Engineering Societies of Pittsburgh held a Smoker at which Mayor Magee talked on subjects of special interest in this district.

Respectfully submitted,

HENRY D. JAMES, *President,*

Governing Council, Associated Engineering Societies of Pittsburgh.

REPORT OF MEMBERSHIP COMMITTEE

To the Board of Direction,

Engineers' Society of Western Pennsylvania:

Dear Sirs:

The Membership Committee beg to report on the work done during the year 1922.

Monthly meetings were held to discuss ways and means to increase the membership, pass on applications received and assign them to the various grades of membership, and to act upon resignations.

The Committee recommended that entrance fees to members of the National Societies be remitted for a period of six months in order to encourage their members to join the Society.

Engraved invitations were sent to a selected list of engineers and executives. In some cases these invitations were followed up with a personal visit by some member of the Committee.

The privileges of the Society and Club Room were extended to the Army, Ordnance and Navy Engineers in the district for their term of office, without payment of dues. The Chief of the Bureau at Washington was advised of this action.

Two suggested methods of increasing the membership have been proposed, which we feel, if followed up, will result in some valuable members for the Society. First—The Secretary to send out a postal card asking the members to send in one or more names of engineers who should join the Society. Second—A list to be prepared of companies in this district, and certain members of the Committee to be assigned to these companies to see their executives with a view to securing their aid in obtaining new members for the Society from their engineering departments.

At the close of the year the membership of the Society was as follows:

Honorary Member	1
Members	1120
Associate Members	89
Associates	30
Juniors	78
Student Juniors	2
	1320
Dropped	37
Resignations	47
Removed by death	9
	93
Accessions	107

This membership represents an active membership, and it is this type of membership that the Society desires to maintain, as practically all of the dead timber has been dropped.

The Membership Committee would again bespeak your active assistance in increasing the membership of your Society, for it feels that the services of the Society to the community can be greatly increased by increasing the number of engineers who are actively engaged in its work.

Respectfully submitted,

John A. Hunter, *Chairman.*

REPORT OF CIVIC AFFAIRS COMMITTEE

To the Board of Direction,

Engineers' Society of Western Pennsylvania:

Dear Sirs:

The Civic Affairs Committee submits report of activities during the year 1922 as follows:

Meeting held September 28th to endorse resolution in regard to filling vacancy occasioned by the death of J. G. Chalfant, County Engineer. Resolution passed, suggesting that careful consideration be given to the appointment to this office and that the personnel of the County Engineer's office be considered as to length of service, etc. Referred to the Associated Engineering Societies for their approval.

Meeting held September 15th to consider letter from Citizens' Committee on City Plan of Pittsburgh asking Council that they adopt a program

on Playground Development before spending any further money on this work. Also letter from Department of City Plan of Pittsburgh asking that the Society arrange for a meeting at which one of their Committee be asked to speak on the proposed zoning ordinance. Both letters referred to the Associated Engineering Societies of Pittsburgh, with the recommendation that such a program be adopted and that a meeting be held on October 28th on the zoning proposition.

Respectfully submitted,
Morris Knowles, *Chairman.*

REPORT OF ENTERTAINMENT COMMITTEE

Board of Direction,
Engineers' Society of Western Pennsylvania:

Dear Sirs:

The Entertainment Committee beg to report on work done by the Committee during the year 1922.

March 18th—Inspection trip; attendance 85; American Window Glass Co., Arnold plant.

May 11th—Smoker; attendance 135; held under auspices of Associated Engineering Societies of Pittsburgh.

May 26th—Dinner; American Engineering Council; attendance 93.

Due to the coal shortage and the labor situation, together with the general business depression, it has been impossible to schedule our usual

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number of inspection trips during the past year, inasmuch as the majority of plants were shut down on Saturdays, and past experience has proved it inadvisable to hold these trips on any day but Saturday.

All arrangements are completed for the Annual Banquet to be held January 22nd, and present indications point to one of the largest dinners we have ever had.

Respectfully submitted,
George T. Ladd, *Chairman.*

REPORT OF FINANCE COMMITTEE

To Board of Direction,
Engineers' Society of Western Pennsylvania:

Dear Sirs:

At the beginning of the last fiscal year, by direction of the Board of Direction, your committee made an exhaustive study of the finances of the Society, and under date of March 20, 1922, presented a detailed report, which showed the necessity of an increase in revenue which, it appeared, could be secured only by one of two plans—an increase in the membership of the Society or an increase in dues. The report further recommended the adoption of a budget, and an estimate of receipts and expenses for the year was presented. The Board adopted the budget plan, and we are glad to be able to report that the expenses for the year have been kept within the amount set up in the budget, with the exception of commissions for advertising, but that these will be returned as payments for advertising come in, so that as a matter of fact the expenses have been kept $126.00 below the estimate. The estimated expenses were $16,773.00, and the actual $16,847.00.

The receipts for the year were estimated at $18,442.00. The amount realized was $18,139.90, or $302.10 less than anticipated.

Later in the year the Board acted favorably upon the suggestion of the Finance Committee in the matter of raising dues, and the proposition was referred to the membership for letter ballot, and resulted in a large majority favorable to the increase, so that from now on the finances of the Society should be in good condition. The difficulties of the last few years have been very largely due to increases in the cost of printing and of rent. The present dues should take care of these and provide a surplus sufficient to replace in the permanent and reserve funds the amount which it has been necessary to borrow from them.

On December 31, 1921, the amount of outstanding unpaid bills was $4,879.56. On December 31, 1922, the same item was $1,744.25. In addition, however, there was also a note for $1,500.00 at the Diamond National Bank. The reduction of floating debt during the year, therefore, amounted to $1,635.31.

The amount due the reserve and permanent funds December 31, 1922, $7,445.00, is made up of $2,400.00 borrowed from the reserve fund, $2,000.00 borrowed from the permanent fund, $1,000.00 for a Liberty Bond belonging to the permanent fund and $2,045.00 due the permanent fund for entrance fees and life memberships received, but not yet deposited in this fund.

On account of delays caused by the printers' strike, there were, at the beginning of the year several issues of the last year's Proceedings remaining unprinted. During the year the printer has brought his work up to date, which has made the printing bill larger than it otherwise would have been.

In your Committee's report of March 20, 1922, there were two suggestions which we wish to renew in this report. The first is "that in the future, supplies, etc., for the Society should be purchased upon requisition approved by some committee or individual designated by the Board, or at least that the order for them be approved before the purchase is made. At the present time there is no check by the Board upon purchases made until the voucher for payment comes to the officers of the Board for approval."

The second suggestion which we wish to renew is that there shall be established as soon as the finances of the Society will permit, and we believe that that time has now arrived, a fund from which replacement of furniture and fixtures can be made. In the past the Society has not had such a fund, and when a replacement became necessary it was made out of current funds and charged to ordinary expenses, or the money was borrowed from the permanent fund. Your committee again recommends that a fund be created by setting aside, year by year, a certain percentage, to be fixed by the Board of Direction, of the value of the fixtures and equipment owned by the Society. This should not be a mere bookkeeping proposition, but there should be a real fund created and maintained, from which all replacements should be made.

Respectfully submitted,

W. C. Hawley, *Chairman.*

REPORT OF TREASURER

Board of Direction,

Engineers' Society of Western Pennsylvania:

Dear Sirs:

Your Treasurer begs leave to submit the following report for the year 1922:

Receipts

Dues Collected	$12,744.18	
Life Memberships	300.00	
Entrance Fees	605.00	
Sale of Advertising Space	2,369.37	
Sale of Magazine "Proceedings"	397.10	
Sale of Society Pins	72.00	
Interest on Bonds	732.50	
Interest on Bank Balances	108.36	
Income from Banquet	4,646.00	
Smoker—Associated Engineering Societies of Pittsburgh	135.00	
Income from Dinners, etc., Associated Engineering Societies of Pittsburgh	274.75	
Sale of Rugs and Furniture	140.00	
Miscellaneous	60.85	
Money Borrowed from Bank	4,500.00	
Sale of Liberty Bond—Third Issue	987.49	
		$28,072.60

Disbursements

Administrative and General	$13,495.42	
Sectional Expense	625.08	
Cost of Magazine "Proceedings"	7,385.38	
Associated Engineering Societies of Pittsburgh	513.96	
Annual Banquet 1922	4,545.28	
Annual Banquet 1923	271.62	
Miscellaneous Expenditures	3,281.15	
		30,117.89
Excess of Disbursements		$ 2,045.29

Assets

	Dec. 31, 1921	Dec. 31, 1922
Permanent Fund:		
Bonds	$13,738.00	$12,730 00
Cash (Fidelity T. & T. Co.)	2,194.71	194.71
Reserve Fund:		
Cash (Fidelity T. & T. Co.)	100.00	100.00
General Fund:		
Cash (Diamond National Bank)	302.79	55.50
	$16,335.50	$13 080.21
Decrease in Assets		3,255.29
	$16,335.50	$16,335.50

Investments—Bonds Owned—Permanent Fund

One $1,000 Butler Water Co. 5% Bond, No. 9, maturing September 2, 1931	$ 750.00
Two $1,000 Connellsville Water Co. 5% Bonds, Nos. 317 and 318, maturing October 1, 1930	1,500.00
Two $1,000 Portsmouth, Berkley & Suffolk Water Co. 5% Bonds, maturing November 1, 1944, Nos. 465-66	1,500.00
Two $1,000 Jamison Coal & Coke Co. 5% Bonds, Nos. 1502-1503, maturing November 1, 1931	1,960.00
Two $1,000 Union Steel Co. 5% Bonds, Nos. 38642-38643, maturing December 1, 1952	2,060.00
Two $1,000 Pennsylvania R. R. Co. 4½% Bonds, Nos. 27320-27321, maturing August 1, 1960	1,960.00
Three $1,000 Jones & Laughlin Steel Co. 5% Bonds, Nos. 3020-3021-3022, maturing May 1, 1931	3,000.00
	$12,730.00

The deficit of approximately $2,000.00 in the operation is principally due to the fact that at the end of last year the bills payable amounted to $4,274.47 and to $1,744.25 this year, so that we during this year actually paid $2,530.22 on an accumulated deficit, a deficit so far never appearing on the auditor's report.

The assets of the Society this year are $17,398.20, against $20,221.60 last year. This drop of approximately $3,000.00 is again explained by the figure just given, in conjunction with the further fact that the market value of our bonds this year has been appraised $592.00 lower than last year.

In accordance with letter ballots by our Society $2,000.00 has been transferred from the permanent fund into the general fund, and one Liberty Bond was sold and put into the general fund.

In order to avoid delays in our business transaction and to save unnecessary annoyances to members, also in order to enable the Board to transact the business of our Society in a most judicious and efficient way, I for one hope that the By-Laws of our Society will be revised so as to enable the handling of our finances more nearly like those of other financial institutions.

Respectfully submitted,
A. Stucki, *Treasurer.*

REPORT OF CIVIL SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania:
Dear Sirs:

I beg to submit the report of the work done by the Civil Section during the year 1922.

Five regular meetings of the Section were held during the year. The average attendance at these meetings was 76, the maximum being 105, at the May meeting, and the minimum 38, at the September meeting.

An average of ten participated in the discussion of the several papers presented. The papers presented were:

February 8th—Annual Meeting. "Continuous Traffic Lift Bridges," A. A. Henderson, Asst. Engr., Allegheny County.

March 14th—Address. "Registration of Professional Engineers and Land Surveyors," R. L. Humphrey, Chairman, Board of Registration for Professional Engineers and Land Surveyors.

May 2nd—"Water Front Improvement in the Downtown District," E. K. Morse, Consulting Engineer, Pittsburgh.

September 12th—"Local Earth Movements in Western Pennsylvania," Leonard F. Bechtel, Chf. Engr., Allegheny County.

November 7th—"Drainage Necessary in Connection With Road Improvement," S. D. Foster, Consulting Highway Engineer.

Respectfully submitted,
C. M. Reppert, *Chairman.*

REPORT OF MECHANICAL SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania:
Dear Sirs:

I beg to submit the report of the work done by the Mechanical Section during the year 1922.

Five meetings of the Section were held during the year. The average attendance at these meetings was 110, the maximum being 285, at the February meeting, and the minimum 43, at the June meeting.

An average of five participated in the discussion of the several papers presented. The papers presented were:

February 7th—Annual Meeting. "Powdered Coal for the Generation of Steam," Henry Kreisinger, Research Engr., Combustion Engineering Corp., New York, and John Blizard, Fuel Engr., U. S. Bureau of Mines, Pittsburgh.

April 11th—"Engineering Features of the Herrington Rocking Cableway," B. W. Kerr, President, Railway & Industrial Engineering Co., Greensburg, Pa.

June 6th—"Factors Affecting the Use of Air in Oil Burning, With Comparison of Costs," W. C. Buell, Jr., V. P., Buell, Scheib, Mueller, Inc.

October 10th—"Development of Helical Steel Springs for Flexible Locomotive Motor Drives," W. J. Merten, Metallurgical Engr., Westinghouse Electric & Manufacturing Co.

December 5th—"The Modern Industrial Gear," W. H. Phillips, Mgr., and L. F. Burnham, Mechanical Engr., R. D. Nuttall Co.

Respectfully submitted,

W. E. Moore, *Chairman.*

REPORT OF MINING SECTION

To the Board of Direction,

Engineers' Society of Western Pennsylvania:

Dear Sirs:

I beg to submit the report of the work done by the Mining Section during the year 1922.

Five regular meetings of the Section were held during the year. The average attendance at these meetings was 59, the maximum being 90, at the March meeting, and the minimum 18, at the January meeting.

An average of eight participated in the discussion of the several papers presented. The papers presented were:

January 31st—Annual Meeting. "Standardization of Mine Turnouts," J. D. Martin, Chief Engr., Hillman Coal & Coke Company.

March 28th—"Cement and Concrete in Underground Workings," Robert Linton, Mining Engr., New York City.

May 31st—"Substitution of Mechanical Energy for Human Energy in Underground Loading," J. F. Joy, President, Joy Machine Company.

September 26th—"Longwall System of Mining," R. W. McCasland, Gen. Supt., Wheeling Steel Corp.

November 28th—"The Stripping Method of Mining Coal," S. A. Taylor, Consulting Mining Engineer, Pittsburgh, Pa.

Respectfully submitted,

W. A. Weldin, *Chairman.*

REPORT OF PRACTICING ENGINEERS' SECTION

To the Board of Direction,

Engineers' Society of Western Pennsylvania:

Dear Sirs:

I beg to submit the report of the work done by the Practicing Engineers' Section during the year 1922.

Two meetings of the Section were held during the year. The average attendance at these meetings was 50—96 attending the March 14th meeting and 15 the February 27th meeting.

The regular business of the Section was taken up at the February 27th meeting, and the meeting of March 14th was a joint meeting with the Civil Section of the Society, at which the following address was presented:

"Registration of Engineers and Land Surveyors," R. L. Humphrey, Chairman, State Board for Registration of Professional Engineers and Land Surveyors."

Respectfully submitted,

F. G. Ross, *Chairman.*

REPORT OF STEEL WORKS SECTION

To the Board of Direction,

Engineers' Society of Western Pennsylvania:

Dear Sirs:

I beg to submit the report of the work done by the Steel Works Section during the year 1922.

Three regular meetings of the Section were held during the year. The average attendance at these meetings was 53, the maximum being 89, at the February meeting, and the minimum 36, at the April meeting.

An average of four participated in the discussion of the several papers presented. The papers presented were:

February 28th—Annual Meeting. "Stainless Steel," C.. M. Johnson, Director of Research and Chf. Engr., Crucible Steel Co. of America.

April 25th—"The Making of Steel in India," Barton R. Shover, Consulting Engineer, Pittsburgh, Pa.

June 20th—"Observations at German Iron and Steel Works With Special Reference to Heat Economy," K. Huessener, Mgr., American Heat Economy Bureau.

Respectfully submitted,

Strickland Kneass, Jr., *Chairman.*

REPORT OF SPECIAL COMMITTEE

Mr. H. A. Rapelye, Chairman of the Special Committee appointed by the President to consider the possibility of an Engineers' Club Building, submitted the following report:

"Mr. H. D. James, President,

Engineers' Society of Western Pennsylvania.

Dear Sir:

Some time ago you requested the writer to investigate in a preliminary way the possibility and advisability of establishing an Engineers' Club in Pittsburgh.

I can report to you some progress in this direction, although there are not available at this time figures of conclusive weight in either respect. An investigation is in progress of the potential membership of such a club in this city, and of the detailed organization and success, financial and otherwise, of similar clubs in other cities.

The most substantial progress, however, is an increasing attendance at our Society Rooms, resulting from the availability of restaurant facilities at our present location.

Yours very truly,

H. A. Rapelye."

REPORT OF TELLERS

To the Members,
Engineers' Society of Western Pennsylvania:

Dear Sirs:

The undersigned tellers publicly canvassed the ballots in the annual election of the officers of the Society at noon, January 16th, 1923, and beg to report the following results:

Ballots received 375
Irregular ballots 2

Ballots counted 373

For President—Morris Knowles 371
For Vice President—Walter B. Spellmire.......................... 369
For Treasurer—A. Stucki 373
For Directors—F. I. Ellis 372
E. D. Leland.. 369

Respectfully submitted,

L. C. Frohrieb,
R. M. Rush,
W. H. Scheib,
Tellers.

The President thereupon declared the following men elected:

For President ....Morris Knowles
For Vice President ....Walter B. Spellmire
For Treasurer ....A. Stucki
For Directors................F. I. Ellis and E. D. Leland

President James appointed Past Presidents A. Stucki and W. C. Hawley to escort the President-elect to the chair.

President Knowles announced the appointment of the following Chairmen for Standing Committees for the year:

E. D. Leland...............................Chairman, House Committee
George T. Ladd........................Chairman, Finance Committee
Walter B. Spellmire........Chairman, Membership Committee
J. C. Hobbs....................Chairman, Entertainment Committee
Frederic Crabtree..............Chairman, Publication Committee
Louis P. Blum..........Chairman, Committee 100 Ft. Standard
Frank I. Ellis..................Chairman, Civic Affairs Committee

There being no further business before the Society, the address of the retiring President, on "Vertical Transportation," was presented by Mr. Henry D. James, Manager, Control Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

The ensuing discussion was participated in by: W. M. Austin, Elec. Engr., Supply Engineering Dept., Westinghouse Elec. & Mfg. Co.; H. F. Bucher, Employment Mgr., Philadelphia Company; W. C. Buell, Jr., Pres., Buell, Scheib, Mueller, Inc.; G. E. Flanagan, Mech. Engr., Heyl & Patterson, Inc.; Morris Knowles, Pres., Morris Knowles, Inc.; A. G. McGarvey, Chf. Engr., William Penn Hotel, Pittsburgh Hotels Co.; E. O. Mueller, Secy., Buell, Schieb, Mueller, Inc.; L. J. Schwartzman, Schwartzman & Co.; W. F. Sanville, Pres., Specialties Co. of Pittsburgh; M. W. von Bernewitz, Mining and Metallurgical Engr., U. S. Bureau of Mines; W. A. Weldin, Blum, Weldin & Co.; and the author.

There being no further discussion, the meeting adjourned at 10:15 P. M.

K. F. Treschow, *Secretary.*

MINING SECTION

The Annual Meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, January 30th, at 8:25 P. M., Chairman W. A. Weldin presiding, 38 members and visitors being present.

The Minutes of the last Annual Meeting were read and approved.

The Annual Report of the Chairman was read by the Secretary.

The report of the Nominating Committee was read by Chairman H. H. Rankin, as follows:

"Officers and Members Mining Section,
Engineers' Society of Western Pennsylvania:

Dear Sirs:

Your Nominating Committee has appointed the following nominees for the several offices of the Section for the ensuing year:

Chairman	H. N. Eavenson
Vice Chairman	E. H. Coxe
Directors	J. O. Durkee J. R. Elliott M. D. Gibson J. M. Rayburn E. S. Taylor

Respectfully submitted,
J. D. MARTIN, Chairman,
G. S. BATON,
H. H. RANKIN,
Nominating Committee."

On motion, the nominations were closed and the Secretary was instructed to cast a unanimous ballot in favor of the officers named, and they were, therefore, declared elected.

There being no further business, the meeting adjourned and the regular bi-monthly meeting was called to order by Mr. Weldin.

There being no further business, the paper of the evening, on "The Application of Fans to the Ventilation of Coal Mines," by Mr. J. R. Robinson, President, Robinson Ventilating Co., Pittsburgh, Pa., was read.

The ensuing discussion was participated in by: H. H. Rankin, Civil and Mining Engr., Pittsburgh, Pa.; W. A. Weldin, Blum, Weldin & Co.; J. O. Durkee, Mining Engr., Pittsburgh, Pa.; H. P. Greenwald, Assistant Physicist, U. S. Bureau of Mines; and the author.

There being no further discussion, the meeting adjourned at 9:32 P. M.

K. F. TRESCHOW, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor "D," William Penn Hotel, Tuesday, February 20, 1923 at 4:30 P. M., President Morris Knowles presiding, Messrs. Crabtree, Spellmire, Ladd, Hildner, Khuen, Leland, Thayer, Ross, Danforth and the Secretary being present.

The minutes of the last meeting held January 16th were approved without reading.

Applications for membership from the following gentlemen, having been previously published to the Society, in accordance with the action of the Board, were elected to membership.

MEMBERS

Burgess, Charles Calvin
McConnell, Charles H.
Peirce, W. Bradford

ASSOCIATE MEMBERS

Halbert, Charles Raymond

STUDENT JUNIOR

Wishoski, Ignatius Stanley

Applications for membership were received from the following gentlemen and were graded by the Membership Committee as follows:

MEMBERS

Brown, Charles F.
Kuhman, Louis F.
Laboon, John F.

ASSOCIATE MEMBERS

Lambie, Joseph Sioussa
Dilworth, Edward Coe
Davis, D. E.
Campbell, John T.
Horelick, Harry
Keim, Byron L.
Reese, David M.

JUNIOR

Dreux, Alexander John

Secretary presented an application for transfer to higher grade from Mr. F. K. Howell, and after discussion he was transferred to the grade of Member.

The report of the Secretary showing the financial condition of the Society at the close of business, January 31st, having been audited by the Finance Committee, was approved.

COMMITTEE REPORTS

Mr. Knowles announced the appointment of Mr. Richard Khuen, Jr., as Chairman of the Civic Affairs Committee and stated that Mr. Khuen would announce the personnel of his committee at the next meeting of the Board.

In the absence of Mr. Hobbs, Chairman of the Entertainment Committee, the Secretary announced the following members of the Committee for the coming year, who were approved by the Board: C. W. Bennett, A. S. Davison, R. E. Butler, T. C. Clifford, A. Hurlburt, Charles Schley and T. F. Webster. The Secretary stated that Mr. Hobbs intended to call his committee together next week to arrange for a social program for this year.

Mr. Ladd, Chairman of the Finance Committee announced the personnel of his committee as follows: Taylor Allderdice, W. E. Fohl, A. L. Humphrey and G. G. Coolidge.

Mr. Leland, Chairman of the House Committee announced the appointment of Messrs. L. C. Frohrieb and William F. Hall to serve on his committee for the ensuing year. These names were approved by the Board.

Mr. Spellmire, Chairman of the Membership Committee presented the following report and announced the appointment of the following men as members of his committee for the year: Messrs. J. R. Buchanan, W. C. Buell, J., W. D. Chester, H. R. Cornelius, J. L. deVou, W. R. Jarvis, H. A. Rapelye, E. Rahm, Jr., B. R. Shover, and G. E. Stoltz, which names were approved by the Board.

The Membership Committee held one meeting at which the various applications received since the last meeting of the Board were gone over and assignment made to the various grades of membership.

It was recommended that ten of the resignations received be accepted.

It was recommended that one member applying for transfer to higher grade be transferred to the grade of Member.

It was moved and carried that the report of the Committee be approved.

Mr. Crabtree, Chairman of the Publication Committee announced the appointment of the following men to serve on his committee: G. M. Baker, A. E. Crockett, E. P. Dandridge, H. N. Eavenson, F. I. Ellis, F. E. Leahy, K. Seaver, Clay Sprecher, H. R. Thayer and H. P. Tiemann. It was moved and carried that the names be approved.

The Secretary retired from the room during the election of a Secretary and K. F. Treschow was reelected with an increase in salary of $25.00 per month.

The Secretary presented a letter received from Mr. D. Winters, President of Council of the City of Pittsburgh enclosing copy of the proposed Zoning Ordinance recently presented to Council asking that our organization study this Ordinance and make recommendations as to its approval.

Mr. Winters stated that copies were being sent to all organizations in Pittsburgh interested in Civic Betterment, inasmuch as Council felt that all those interested should be heard and their recommendations or objections filed before final action was taken. It was further stated that on Thursdays during the months of March and April public hearings will be held.

After a general discussion, it was moved and carried that this matter

be referred to the Civic Affairs Committee with the request that they study this Ordinance and make definite recommendations to the Board of Direction.

The meeting adjourned at 3:40 P. M.

K. F. Treschow, *Secretary.*

MECHANICAL SECTION

The Annual Meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in 209 Science Building, Carnegie Institute of Technology, Tuesday, February 13th at 8:00 P. M. The Secretary presiding in the absence of the Chairman, 32 members and visitors being present.

The Minutes of the last Annual Meeting were read and approved.

The Annual report of the Section was read by the Secretary.

The report of the Nominating Committee was read by Mr. F. K. Howell:

Your Nominating Committee has appointed the following nominees for the several officers of the Section for the ensuing year.

E. P. Dandridge, Chairman.
J. A. Morton, Vice Chairman.
W. C. Buell, Jr.
E. J. Deckman
R. E. Polk
G. T. Swarts
F. M. VanDeventer

} Directors

Respectfully submitted,

T. F. Webster, *Chairman,*
F. K. Howell,
C. F. Freeman,
Nominating Committee.

On motion the nominations were closed and the Secretary instructed to cast a unanimous ballot in favor of the officers named and they were, therefore, declared elected.

There being no further business, the meeting adjourned and the regular bi-monthly meeting was called to order.

There being no further business before the regular meeting, Walter Rosenhain, A. B., Sc. D., F. R. S., noted English Engineer & Scientist and Superintendent Metallurgical Dept., National Physical Laboratory, Teddington, England, made an address on Metallurgy.

The meeting adjourned at 9:40 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The 410th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, February 20th at 8:10 P. M., President Morris Knowles presiding, 29 members and visitors being present.

The Minutes of the last regular meeting held December 12th, were read and approved.

The Board of Direction reported the election of one applicant to the grade of Member, one to the grade of Associate Member and one to the grade of Junior. The receipt of five applications for membership, one reinstatement and ten resignations.

No further business coming before the Society, the paper of the evening on European Electrified Railways was presented by Mr. F. E. Wynne, Manager, Railway Equipment, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

The ensuing discussion was participated in by: Morris Knowles, President, Morris Knowles, Inc.; J. L. Entwisle, Engr., Railway Equipment, Westinghouse Elec. & Mfg. Co.; George H. Danforth, Struct. Engr., Jones & Laughlin Steel Corp.; C. M. White, Supt., Monongahela Connecting Railway Co.; W. M. Austin, Elec. Engr., Westinghouse Elec. & Mfg. Co.; and the author.

It was moved and carried unanimously that a vote of thanks be extended to Mr. Wynne for his very excellent paper.

The motion adjourned at 9:40 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Crystal Parlor, William Penn Hotel, Tuesday, March 20th at 4:40 P. M. President Morris Knowles presiding, Messrs. Crabtree, Spellmire, Hildner, Khuen, Hobbs, Leland, Ludgate, Eavenson, Martin, Danforth and the Secretary being present.

The Minutes of the last meeting held February 20, 1923 were approved without reading.

Applications for membership from the following gentlemen having been previously published to the Society, in accordance with the action of the Board, were elected to membership.

MEMBERS

Brown, Charles F.
Laboon, John F.
Kuhman, Louis F.

ASSOCIATE MEMBERS

Campbell, John T.
Dilworth, Edward Coe
Davis, D. E.
Horelick, Harry
Keim, Byron L.
Lambie, Joseph Sioussa
Reese, David M.

JUNIOR

Dreux, Alexander John

Applications for membership were received from the following gentlemen and were graded by the Membership Committee as follows:

MEMBERS

Gosselin, Edward N.
Stangland, Oliver
Peirce, Charles L. Jr.
Davies, John W.
Bain, Joseph G.
Culler, Aaron Andrew

ASSOCIATE MEMBERS

McMaster, Arthur J.
Whigham, William Jr.

Letter was received from Mr. David Henderson, asking to be reinstated to membership. After discussion the Secretary was requested to advise Mr. Henderson that his name had been placed on the Society Rolls.

The Secretary reported the death of Mr. Howard Wilson, who joined the Society Jan. 1886 and died Feb. 16, 1923; Mr. E. P. Donohue who

joined March 1904, also Mr. Walter Schmidt who joined the Society Feb. 1902 and died January 1923.

The report of the secretary, showing the financial condition of the society at the close of business, February 28th, having been audited by the Finance Committee, was approved.

In connection with the above report, the Secretary reported that in accordance with action taken at the last meeting of the Board we had employed an assistant in the Society office and had started a campaign for increasing our advertising, which has resulted up to the present time in securing advertising totaling $2084.00. This amount under our previous arrangement with advertising solicitor, means that we have saved $938.00.

The Secretary reported further that we had to-day received check from the Jones & Laughlin Steel Corp. and that others were expected in the near future.

COMMITTEE REPORTS

The Secretary, on behalf of the Civic Affairs Committee, presented the following report:

To Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

In accordance with your instructions of Feb. 20, 1923, your Civic Affairs Committee has studied the final report of the Zoning Ordinance for Pittsburgh, as submitted by the Dept. of City Planning, and begs to submit the following:

On account of the short time allotted the Committee it was found impracticable to present detailed suggestions to any great extent.

It appears to be the consensus of opinion of experts that Zoning is advisable; accepting this opinion as correct, the general plan submitted by the Dept. of City Planning meets with the approval of your Committee since it gives evidence of very careful study.

"USE" DISTRICT CLASSIFICATION. Your Committee endorses this classification as it follows the natural development of the city up to the present time and such prospective development as can be foreseen.

"HEIGHT" DISTRICT CLASSIFICATION. Your Committee has no objection to this classification, except in the Maximum Height District, viz. 125 ft. plus the set back stories. Believing that some limit should be fixed for the extreme height of buildings,—Your Committee, nevertheless, has not yet been able to reach an agreement as to what this limiting height should be.

Inasmuch as the proper height limit for Pittsburgh is entirely one of judgment, we believe this question should be given further careful study so that Pittsburgh shall not repeat the experience of Chicago, where the height limit has been changed several times between the limits of 130 and 260 ft.

As this question involves the economical height of buildings real estate values, the general health and safety of the community, together with prospective transportation and public utility developments, your Committee recommends that further consideration be given this question.

"AREA" DISTRICT CLASSIFICATION. This portion of the report appears to be well worked out and meets with the approval of the Committee.

ADMINISTRATION. The successful administration of this ordinance manifestly depends upon the judgment and impartiality of the Board of Appeal. Ample provision seems to have been made for correcting original errors or unfair classification, where such can be proved, by authorizing changes through the action of the City Planning Commission and City Council.

The Committee assumes that modification of zones can be made from time to time in order to take care of the natural industrial and commercial development of the city as cannot now be foreseen.

Respectfully submitted,
Committee
Richard Khuen, *Chairman*,
J. Toner Barr,
Thos. Fleming, Jr.,
James O. Handy,
Wm. E. Mott,
Harry J. Lewis.

After discussion it was moved and carried that the report be accepted and transmitted to the General Society at its meeting this evening with an amendment in the last paragraph, changing the word "assumes" to "understand" and omitting the sentence "if not, machinery should be provided for this purpose".

The Secretary reported on behalf of the Entertainment Committee stating that the Committee had held one meeting during the past month, at which a general program of inspection trips and other social functions were planned. The Committee hopes to have inspection trips every other Saturday, starting with a trip next Saturday through the Liberty Tunnels notice of which has been mailed, and terminating the middle of June.

In the absence of Mr. Ladd, Chairman of tthe Finance Committee, the Secretary reported that efforts were being made to secure additional advertisements and collect back dues, owing the Society.

Mr. Spellmire, Chairman of the Membership Committee, reported that one meeting of the Committee has been held to assign the application on to the various grades of membership.

Nine resignations were received and after discussion it was recommended that they be accepted.

It was recommended that Mr. Henderson applying for reinstatement be placed on the Society Rolls in the same grade of membership as he was previously.

The question of increasing the membership was taken up and it was decided that the plan inaugurated by the Committee last year be continued and after the list has been made up that Mr. Buell and the Secretary call upon the men on this list and report back to the Committee.

The Secretary presented a letter from the Engineers' Club of Philadelphia in regard to a bill introduced in the Pennsylvania Legislature to repeal the Act Licensing Engineers in this State, in which it was stated this has been brought before a meeting of their organization where the following resolution had been passed.

"WHEREAS, a Bill (Senate Bill No. 59, House of Representatives No. 53) has been introduced in the Pennsylvania Legislature to repeal—An Act to regulate the practice of the profession of engineering and land surveying creating a state board for the registration of professional engineers and land surveyors, defining its powers and duties. Imposing certain duties upon the commonwealth and political sub-divisions thereof in connection with public work and providing penalties—which last named act

was approved the 25th day of May, 1921, F. L. 422, page 1121, of the Acts of 1921, therefore, be it

RESOLVED, that in the opinion of the members of the Engineers' Club of Philadelphia, assembled in business meeting this first day of March 1923, the repeal of said act would militate against the best interests of the profession."

An expression from the Engineers' Society of Western Pennsylvania is requested.

After a general discussion, the letter was referred to the Civic Affairs Committee.

Mr. Knowles called attention to the fact that one of our Directors, Mr. Ladd, had been ill for sometime and it was moved and carried that a letter be sent him expressing regret at his illness and the hope of his speedy recovery.

The meeting adjourned at 5:30 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

The 411th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, March 20th at 8:13 P. M., President Morris Knowles presiding, 94 members and visitors being present.

The Minutes of the last meeting held February 20th were read and approved.

The Board of Direction reported the election of three applicants to the grade of Member, one to the grade of Associate Member and one to the grade of Student Junior and the receipt of eleven applications for membership. One member was transferred to higher grade and ten resignations received.

The report of the Civic Affairs Committee on the letter received from the President of City Council on the Zoning Ordinance, which had been approved by the Board of Direction and ordered presented to the General Society, was presented as follows:

In accordance with the instructions of Feb. 20, 1923, your Civic Affairs Committee has studied the final report of the Zoning Ordinance for Pittsburgh, as submitted by the Dept. of City Planning and begs to report the following:

On account of the short time allotted your Committee it was found impracticable to present detail suggestions to any great extent.

It appears to be the consensus of opinion of experts on Civic Affairs that zoning is advisable; accepting this opinion as correct the general plan submitted by the Dept. of City Planning meets with the approval of your Committee since it gives evidence of very careful study.

"USE" DISTRICT CLASSIFICATION. Your Committee endorses this classification as it follows the natural development of the city up to the present time and such prospective development as can be foreseen.

"HEIGHT" DISTRICT CLASSIFICATION. Your Committee has no objection to this classification, except in the Maximum Height District, viz. 125 ft. plus the setback stories. Believing that some limit should be fixed for the extreme height of buildings,—Your Committee, nevertheless, has not yet been able to reach an agreement as to what this limiting height should be.

Inasmuch as the proper height limit for Pittsburgh is entirely one of judgment, we believe this question should be given careful study so that Pittsburgh shall not repeat the experience of Chicago, where the height limit has been changed several times between the limits of 130 and 260 ft.

As this question involves the economical height of buildings, real estate values, the general health and safety of the community, together with prospective transportation and public utility developments, your Committee recommends that further consideration be given this question.

"AREA" DISTRICT CLASSIFICATION. This portion of the report appears to be well worked out and meets with the approval of the Committee.

ADMINISTRATION. The successful administration of this ordinance manifestly depends upon the judgment and impartiality of the Board of Appeal. Ample provision seems to have been made for correcting original errors or unfair classification, where such can be proved, by authorizing changes through the action of the City Planning Commission and City Council.

The Committee assumes that modifications of zones can be made from time to time in order to take care of the natural industrial and commercial development of the city as cannot now be foreseen.

CIVIC AFFAIRS COMMITTEE

Richard Khuen, Jr., Chairman,
J. Toner Barr,
Thos. Fleming, Jr.,
James O. Handy,
Wm. E. Mott,
Harry J. Lewis.

It was moved and carried that the report of the Committee be approved and that the matter of Height of Buildings be referred back to them with instructions that they report direct to City Council after they had reached a decision.

Mr. Danforth presented an amendment to the above motion requesting the Committee to report back to the Society rather than to Council.

After discussion it was moved and carried that the motion be adopted including Mr. Danforth's amendment.

No further business coming before the Society, the paper of the evening on "A General Plan for Increasing the Capacity of the Railroad Systems in the Pittsburgh District" was presented by Mr. George S. Davison, President, Gulf Refining Co., Pittsburgh, Pa., and Mr. Norman W. Storer, General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

The ensuing discussion was participated in by: S. A. Taylor, Consulting Engineer; Harry J. Lewis, Consulting Engineer; Robert Trimble, Chf. Engr., M. of W. Pennsylvania Company; and the authors.

On motion the meeting adjourned at 10:36 P. M.

K. F. Treschow, *Secretary*.

MINING SECTION

The regular bi-monthly meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, March 27th at 8:15 P. M., Chairman H. N. Eavenson presiding, 35 members and visitors being present.

The minutes of the last regular meeting held November 28th, were read and approved.

No further business coming before the Section, the paper of the evening was presented by Mr. R. G. Johnson, President, R. G. Johnson Co. Pittsburgh, Pa. on "Present Practice in Design and Sinking of Mine Shafts".

The ensuing discussion was participated in by: F. A. McDonald, Chf. Engr. & Gen. Supt., National Mining Co.; H. N. Eavenson, Cons. Mining Engr., Howard N. Eavenson and Associates; E. T. Gott, V. P., Dravo Contracting Co.; J. O. Durkee, Mining Engineer; J. R. Elliott, Baton & Elliott; and the author.

On motion duly seconded and carried, a vote of thanks was extended to Mr. Johnson for his very interesting and instructive paper.

The meeting adjourned at 9:47 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Crystal Parlor, William Penn Hotel, Tuesday, April 17th at 4:40 P. M. President Morris Knowles presiding, Messrs: Crabtree, Spellmire, Hobbs, Khuen, James, Ludgate, Martin and the Secretary being present.

The Minutes of the last meeting held March 20th were approved without reading.

Applications for membership from the following gentlemen, having been previously published to the Society, in accordance with the action of the Board, were elected to Membership.

MEMBERS

Bain, Joseph G.
Culler, Aaron Andrew
Davies, John W.
Gosselin, Edward N.
Peirce, Charles L., Jr.
Stangland, Oliver

ASSOCIATE MEMBER

McMasters, Arthur J.

JUNIOR

Whigham, William, Jr.

Applications from the following gentlemen were received and were graded by the Membership Committee as follows:

MEMBERS

Eaton, Henry Taylor
Haag, Louis Wm.
Kennedy, Joseph Walker
Miller, Henry Barron
Miller, James M.
Morrissey Peter J.
Norman, Fred
Ramsey, John Negley
Sloman, Morley S.

ASSOCIATE MEMBERS

Ballard, Bon James
Lytle, James H.
McBerty, Donald Roy
Medley, Harold Cockrell
Schaller, Robert H.

ASSOCIATE

Ballard, Douglas Keene

JUNIOR

Jensen, Scott

The Secretary presented applications for transfer to higher grade of membership from the following gentlemen and after discussion, they were transferred to the grade of Member.

Campbell, J. T.
Lambie, J. S.
Davis, D. E.

The Secretary reported the death of Mr. W. H. Warwick who joined the Society January 1918 and died March 20, 1923.

The report of the Secretary, showing the financial condition of the Society at the close of business March 31st, having been audited by the Finance Committee, was approved.

COMMITTEE REPORTS

To Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

In accordance with instructions received through action of the General Society at its meeting held March 20th, when the matter of the height of buildings in the proposed Zoning Ordinance was referred back to the committee with the request that they go into the matter further and report back, we beg to submit the following:

After studying this matter carefully four members of the Committee out of six believe that the following paragraph should be substituted for the one now appearing in the Proposed Ordinance, as submitted by the Citizens Committee on City Plan. The other two members of the Committee did not feel that they were ready to reach any decision.

"SECTION 23, MAXIMUM HEIGHT DISTRICT. In this district the height shall be limited to one hundred and twenty-five (125) feet when the building abuts on a street fifty (50) feet wide or less; when the building abuts on a street more than fifty (50) feet wide, the maximum height may be two and a half (2½) times this width, but not exceeding one hundred and eighty (180) feet. Additional stories may be added, provided that above such heights, fixed by the above limitations, no point in the wall of any frontage of the building shall be nearer to the vertical plane through any street line than a distance equal to one half the height of such point above the limiting heights fixed above, and provided such extra height shall not exceed the width of the widest street upon which the building abuts, and provided further that no dwelling, except a hotel, shall exceed the height limits limitation prescribed above for the seventy-five (75) foot districts.

(See Section 21, 26, 27, 28 and 29)"

In regard to the matter of the widening of Cherry Way, referred to the Committee at the last meeting of the Board, it was thought best in view of the information secured to delay action until a later date.

Respectfully submitted,
Richard Khuen, *Chairman,*
Civic Affairs Committee.

After discussion it was moved and carried that the report of the Committee be approved and that it be transmitted to the General Society at its meeting tonight with the recommendation of the Board of Direction.

Mr. Hobbs, Chairman of the Entertainment Committee, reported a very successful trip through the plant and mine of the West Penn Power Co. at

Springdale. Due to the inclemency of the weather we did not have the attendance we might have had. However, there were 128 present the trip was thoroughly enjoyed by all. The Committee is still planning an entertainment of some nature during April or May, detailed announcement of which will be made later.

Mr. Leland, Chairman of the House Committee, reported an evening attendance for the month of March of 162.

Mr. Spellmire, Chairman of the Membership Committee, reported that one meeting of the Committee had been held during the month to go over applications received since the last meeting of the Board of Direction and make assignment to the various grades of membership. Also to act upon any resignations received.

The Secretary presented a letter from the National Conference on City Planning asking that we appoint delegates to the Conference in Baltimore, April 30th, May 1st and 2nd. It was moved and carried that Mr. Knowles represent the Society at this conference.

The Secretary presented a letter from Pennsylvania State College asking that we appoint delegates to attend the election of Trustees to be held June 12th. It was moved and carried that the Secretary be instructed to appoint these delegates from members of the Society who are graduates of Penn State.

The Secretary presented a letter from the Cleveland Engineering Society asking that we endorse their action in requesting the U. S. Senators and Representatives to enact legislation to provide for a special technical board to investigate and report on the Improvement of the St. Lawrence River as recommended by the International Joint Commission, appointed by the Canadian and U. S. Government to investigate and report on the Improvement of the St. Lawrence River between Lake Ontario and the City of Montreal for navigation and power. After discussion it was moved and carried that this matter be referred to the Civic Affairs Committee.

Mr. Knowles called the attention of the Board to the fact that on Monday, April 23rd, Brig. General R. C. Marshall, Jr., General Manager of the Associated Contractors of America and Chief of the Construction Division of the army during the war, will speak before the Hungry Club in the English Room of the Fort Pitt Hotel. Mr. Knowles further stated that several National and local societies had recently passed resolutions asking that a prompt trial be given those indicted in order that the innocent may be freed from the serious accusations against them, thereby removing the stigma under which they are now placed.

After discussion, the following resolution was passed.

WHEREAS, The United States Government has brought civil suit against certain engineers and contractors to recover millions of dollars for alleged fraud during the construction of camps, etc. during the war, and

WHEREAS, The wide publicity given these charges has placed a stigma upon the reputation of many prominent engineers, and

WHEREAS, The engineering profession responded promptly to the call of their country and gave generously of their means and services throughout the great war, and

WHEREAS, The Constitution of the United States guarantees to every accused citizen a speedy trial, Therefore,

BE IT RESOLVED That the Engineers' Society of Western Pennsylvania believes that justice demands a prompt trial, and urges that this be granted, so that those who are innocent may be speedily freed from the serious accusation which has been made against them, and

BE IT FURTHER RESOLVED, That copies of this preamble and these resolutions be sent to the President of the United States, to the Attorney General, to the presiding officers of the U. S. Senate and U. S. House of Representatives, and to the U. S. Senators and Representatives of the State of Pennsylvania.

This resolution is along the lines of those adopted by the various other Societies.

The meeting adjourned at 5:45 P. M.

K. F. Treschow, *Secretary.*

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, April 3rd at 8:15 P. M. Mr. W. C. Buell acting as chairman in the absence of Mr. E. P. Dandridge, 76 members and visitors being present.

The Minutes of the last regular meeting held Dec. 5th, were read and approved.

No further business coming before the Section, the paper of the evening on "Recent Development in the Field of the Air Cooled Motor" was presented by Mr. Louis Stellman, Chief Engineer, and C. P. Grimes, Research Engineer, H. H. Franklin Manufacturing Co., Syracuse, N. Y.

The ensuing discussion was participated in by: W. Trinks, Professor Mechanical Engineering, Carnegie Inst. of Technology; S. B. Ely, Asst. Professor, Commercial Engineering, Carnegie Inst. of Technology; A. E. Blake, Pgh. Repr., U. G. I. Contracting Co.; H. A. Rapelye, Manufacturers' Agent; F. F. Espenschied, Engr., City Transportation, Commercial Truck Co. of Philadelphia; A. Stucki, Consulting Engineer; W. D. Hockensmith, V. P. & Gen. Mgr., Hockensmith Wheel & Mine Car Co.; F. L. Egan, V. P. & Gen. Mgr., Ohio and Mississippi Transport Co.; and the author.

On motion duly seconded and carried, a vote of thanks was extended to Messrs. Stellman and Grimes for their very excellent paper.

On motion the meeting adjourned at 10:50 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The 412th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, April 17th, at 7:45 P. M., President Morris Knowles presiding, 76 members and visitors being present.

The Minutes of the last meeting held March 20th, were read and approved.

The Board of Direction reported the election of three applicants to the grade of Member, seven to the grade of Associate Member and one to the grade of Junior and the receipt of eight applications for membership. Also one member reinstated and ten resignations received.

A motion picture was shown of a powdered coal plant before the presentation of the paper of the evening.

The report of the Civic Affairs Committee on "Maximum Height District" in the Zoning Ordinance held over from the last meeting, was presented as follows:

To Board of Direction,

Engineers' Society of Western Penna.

Dear Sirs:

In accordance with the instructions received through action of the General Society at its meeting held March 20th, when the matter of Height of Buildings in the proposed Zoning Ordinance was referred back to this Committee with the request that they go into the matter further and report back, we beg to submit the following:

After studying this matter carefully four members of the Committee out of six believe that the following paragraph should be substituted for the one now appearing in the Proposed Ordinance as submitted by the Citizens Committee on City Plan. The other two members of the Committee did not feel that they were ready to reach any decision.

"SECTION 23—MAXIMUM HEIGHT DISTRICT. In this district the height shall be limited to one hundred and twenty-five (125) feet when the building abuts on a street fifty (50) feet wide or *less*: when the building abuts in a street *more* than fifty (50) feet wide, the maximum height may be two and one-half (2½) times this width, but not exceeding one hundred and eighty(180) feet. Additional stories may be added, provided that above such height fixed by the above limitations, no point in the wall of any frontage of the building shall be nearer to the vertical plane through any street line than a distance equal to one-half the height of such point above the limiting heights fixed above, and provided such extra height shall not exceed the width of the widest street upon which the building abuts, and provided further that no dwelling, except a hotel shall exceed the height limitations prescribed for the seventy-five (75) foot district.

(See Section 21, 26, 27, 28 and 29)

Respectfully submitted,

Richard Khuen, Jr., Chairman,
Civic Affairs Committee.

On motion, duly seconded and carried, the resolution was adopted.

On motion a vote of thanks was extended to Mr. Harter representative of the Chicago Railway Equipment Co. for his courtesy in showing the film mentioned above.

The Secretary read an invitation to the Society to attend the meetings of the Spring Convention of the American Institute of Electrical Engineers, April 24-26th. On motion the courtesies of the Society's Rooms was extended to the Institute during its sessions.

No further business coming before the Society, the paper of the evening was presented by Mr. Ralph Rainsford, Chief Engineer, Philadelphia Company, Pittsburgh on "The Principles of Warfare, Business, and Engineering.

The ensuing discussion was participated in by: A. E. Anderson, Attorney, Pittsburgh, Pa.; J. Franklin Bell, Major, District Engineer, U. S. Engineer Department; Thomas Fitzgerald, Consulting Electrical Railway Engr., Pittsburgh, Pa.; G. E. Flanagan, Mech. Engr., Heyl & Patterson, Inc.; Morris Knowles, Pres. Morris Knowles Inc.; and the author.

On motion duly seconded and carried, the meeting adjourned at 10:15 P. M.

K. F. TRESCHOW, *Secretary*.

STEEL WORKS SECTION

The Annual meeting of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, April 24th at 8:20 P. M., Vice Chairman G. M. Goodspeed presiding in the absence of the Chairman, 67 members and visitors being present.

The Minutes of the last Annual Meeting held Feb. 28, 1922 were read and approved.

The report of the Nominating Committee was read by the Secretary as follows:

To officers and members,
Steel Works Section,

Dear Sirs:

Your Nominating Committee appointed to nominate officers for the Steel Works Section for the ensuing year, beg to submit the following:

Goodspeed, G. M., Chairman. Bradshaw, G. D., Vice Chairman. Shover, B. R. McLaughlin, T. J. Edgar, L. C. Shuman, J. J. Fieldner, A. C.	Directors

Repectfully submitted,
A. Pinkerton, *Chairman,*
G. O. Loeffler,
F. J. Crolius,
Nominating Committee.

It was moved and carried that nominations be closed and the Secretary cast a unanimous ballot for the officers named, who were thereupon declared elected.

There being no further business before the meeting, it was adjourned and the regular bi-monthly meeting called to order by the new Chairman.

The paper of the evening on Water Deactivation was presented by Mr. F. N. Speller, Metallurgical Engineer, National Tube Co., Pittsburgh, Pennsylvania.

Written discussion was presented by: M. F. Newman, Mgr., Water Purifying Dept., Wm. B. Scaife & Sons Co.; Max Hecht, Chemist, Chemical Laboratory, Duquesne Light Co.; J. B. Crane, Engr., George T. Ladd Co.; W. S. Elliott, Pres. The Elliott Co.; Robert Hughes, Chf. Engr., Gerard Estate, Philadelphia, Pa.

The ensuing discussion was participated in by: A. E. Blake, Pgh. Representative, U. G. I. Contracting Co.; Edward O. Mueller, Secy., Buell, Scheib, Mueller, Inc.; J. C. Hobbs, Mgr., Allegheny County Steam Heating Co; G. M. Goodspeed, Metallurgist, National Tube Co.; J. B. Walker, Treas. Pittsburgh Heating Co.; and the author.

On motion the meeting adjourned at 10:12 P. M.

K. F. TRESCHOW, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor "B", William Penn Hotel, Tuesday, May 15th at 4:35 P. M. President Morris Knowles presiding, Messrs. Spellmire, Crabtree, Stucki, Hobbs, Leland, Danforth, James, Ludgate, Goodspeed and the Secretary being present.

The Minutes of the last regular meting held April 17th were approved without reading.

Applications for membership from the following gentlemen, having been previously published to the Society, in accordance with the action of the Board, were elected to membership.

MEMBERS

Eaton, Henry Taylor
Haag, Louis Wm.
Kennedy, Joseph Walker
Miller, Henry Barron
Miller, James M.
Morrissey, Peter J.
Norman, Fred
Ramsey, John Negley
Sloman, Morley S.

ASSOCIATE MEMBERS

Schaller, Robert H.
Ballard, Bon James
Lytle, James H.
McBerty, Donald Roy
Medley, Harold Cockrell

ASSOCIATE

Ballard, Douglas Keene

JUNIOR

Jensen, Scott

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Dermitt, W. Verner
Fulton, James Stewart
Hammond, James R.
Smith-Peterson Nile Oscar

ASSOCIATE MEMBERS

Buxton, Jay James
Homer, William E.

JUNIORS

Bigelow, Jack Edmond
Daniels, Elmer Ralph
Elliott, John Henry
Turner, Athur Arnold

Letters of resignation were received from the following gentlemen and after discussion, the Secretary was requested to write them, accepting their resignations.

Brown, W. D.
Carter, E. B.
Dittmar E. J.

The Secretary reported the death of Mr. H. B. Chess, Jr. who joined the Society January 1908 and died March 30, 1923.

The report of the Secretary, showing the financial condition of the Society at the close of business April 30th, having been audited by the Finance Committee, was approved.

COMMITTEE REPORTS

In the absence of Mr. Khuen, Chairman of the Civic Affairs Committee the Secretary reported that a meeting had been held May 10th at which a communication from the Cleveland Engineering Society in regard to the St. Lawrence River Development was discussed. It was moved and carried that inasmuch as this work was a national problem, it should come under the jurisdiction of the Governing Council of the Associated Engineering Societies of Pittsburgh, rather than the Civic Affairs Committee and the Committee, therefore, recommends that the Board of Direction refer this matter to the Governing Council with favorable recommendation of the Committee for their action.

It was moved and carried that the report of the Committee be accepted and that the communication be referred to the Governing Council of the Associated Engineers' Society of Pittsburgh.

Mr. Hobbs, chairman of the Entertainment Committee, reported a very successful and pleasant evening at the Carnegie Institute of Technology on May 11th, stating that there was an attendance of about 300. The Committee is also arranging for one or two inspection trips later in May or the first of June.

In the absence of Mr. Ladd, chairman of the Finance Committee, the Secretary reported that one new advertisement had been secured from the General Electric Co.

Mr. Leland, Chairman, of the House Committee, reported an evening attendance of 153 for the month of April. He also reported that the Chess Tournament had been completed and the House Committee expected to have the prizes awarded at the regular monthly meeting of the Society in June. Arrangements are now being made for the Bridge Tournament which will start within the next ten days.

Mr. Spellmire, Chairman of the Membership Committee, reported that one meeting of the Committee had been held to assign applications to the various grades of membership.

Three resignations were received and it was recommended that they be accepted.

The Secretary brought up the matter of purchasing a motion picture machine for the Society, stating that if the present plan of the Publication Committee of having a motion picture before each meeting were carried out, it would pay the Society to invest in a machine, as we are obliged to pay $25.00 each time we rented one. He stated further that we had been in communication with the man from whom we had been renting the machine and he agreed to bring the machine for display at the meeting to-night in order that the Board might inspect it.

After a general discussion it was decided, in view of the fact that our meetings are about over for the summer, final decision on this matter

be held over until September meeting of the Board. The members thereupon adjourned to the Blue Room to inspect the lantern.

The meeting adjourned at 5:20 P. M.

K. F. TRESCHOW, *Secretary.*

CIVIL SECTION

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Ball Room, William Penn Hotel, Tuesday, May 1st, at 8:35 P. M., Chaiman B. A. Ludgate presiding, 82 members and visitors being present.

The Minutes of the last regular meeting held January 9th, were read and approved.

There being no further business before the Section, the paper of the evening on "The Bates Test Road" was presented by Mr. R. R. Benedict, Chief Principal Assistant Engineer, Department of Public Works and Buildings, State of Illinois, Springfield, Ill.

There was a general discussion of the paper with a more lengthy discussion by the following: Louis P. Blum, Blum Weldin & Co.; A. E. Anderson, Attorney, Pittsburgh, Pa.; and the author.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Benedict for his very interesting paper.

On motion the meeting adjourned at 10:45 P. M.

K. F. TRESCHOW, *Secretary.*

PRACTISING ENGINEERS' SECTION

The regular meeting of the Practising Engineers' Section of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, May 8th at 8:13 P. M., Chairman P. H. Martin presiding, 42 members and visitors being present.

The Minutes of the last meeing held February 21st, were approved without reading.

No further business coming before the Section, the paper of the evening on "Architecture from an Architect's Viewpoint", was presented by Mr. William Boyd, Ingham & Boyd, Architects, Pittsburgh, Pa.

The ensuing discussion was participated in by: W. A. Weldin, Blum Weldin & Co.; J. M. Rice, Consulting Civil Engineer, Pittsburgh; George H. Danforth, Struct. Engr., Jones & Laughlin Steel Corp.; C. S. Davis, Consulting Engineer, Pittsburgh; and the author.

On motion duly seconded and carried a vote of thanks was extended to Mr. Boyd for his very interesting paper.

Meeting adjourned at 10:10 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

413th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, May 15th at 8:00 P. M. President Morris Knowles presiding, 63 members and visitors being present.

The Minutes of the last meeting held April 17th, were read and approved.

The Board of Direction reported the election of six applicants to the grade of member, one to the grade of Associate Member and one to the grade of Junior; the receipt of sixteen applications for membership; three transfers to higher grade and the receipt of seven resignations.

No further business coming before the Society, Mr. James D. Horn, a native of Russia and a lecturer of national and international fame, addressed the Society on "The Melting Pot of America".

The paper of the evening was presented by Mr. S. B. Williams, Superintendent, Pittsburgh Division, Bell Telephone of Pennsylvania, Pittsburgh, Pa. on "Engineering Problems in the Development of the Telephone Systems".

Motion pictures were then shown of the Underfeed Stoker in operation, by the Sanford-Riley Stoker Co., Worcester, Mass. and showed the stoker in operation both with and without fire.

On motion the meeting adjourned at 10:45 P. M.

K. F. Treschow, *Secretary.*

MINING SECTION

The regular bi-monthly meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, May 29th, at 8:00 P. M. Mr. J. O. Durkee presiding in the absence of the Chairman, 29 members and visitors being present.

The Minutes of the last meeting held March 27th, were read and approved.

No further business coming before the Section, the paper of the evening on "The Problem of Corrosion in the Mining Industry" was presented by Mr. George M. Enos, U. S. Bureau of Mines, Pittsburgh, Pa.

The ensuing discussion was participated in by: A. E. Anderson, Attorney, Pittsburgh; W. M. Austin, Elec. Engr., Westinghouse Elec. & Mfg. Co.; A. E. Blake, Pgh. Repr., U. G. I. Contracting Co.; Philo Kemery, Supt., Open Hearth & Crucible Depts., Cresent Works, Crucible Steel Co. of America; O. J. B. Fraser, Chemist, Mellon Institute, University of Pittsburgh; Max Hecht, Chemist, Chemical Laboratory, Duquesne Light Co.; C Park Fuller, Sales Engr., Harris Pump & Supply Co; J. O. Durkee, Mining Engr., Pittsburgh; and the author.

On motion duly seconded and carried a vote of thanks was extended to Mr. Enos for his very interesting paper.

The meeting adjourned at 10:15 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor E, William Penn Hotel, Tuesday, June 12th at 4:40 P. M. President Morris Knowles presiding Messrs. Crabtree, Spellmire, Stucki, Khuen, Leland, Danforth and the Secretary being present.

The Minutes of the last meeting held May 15th were approved without reading.

Applications for membership from the following gentlemen, having been previously published to the Society in accordance with the action of the Board, were elected to memberhip.

MEMBERS.

Dermitt, W. Verner
Fulton, James Stewart
Hammond, James R.
Smith-Peterson, Nils Oscar

ASSOCIATE MEMBERS.

Buxton, Jay James
Homer, William E.

JUNIORS.

Bigelow, Jack Edmond
Daniels, Elmer Ralph
Elliott, John Henry
Turner, Arthur Arnold

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS.

Fear, Thomas George
McGonagle, Arthur
Schraishuhn, Theodore Adolphus
Stockdale, Henry S.

ASSOCIATE MEMBERS

Ogden, Benjamin M.
Ehmann, R. L.
Harkness, John C.
Wharton, William B.

ASSOCIATES.

Briscoe, James
Cox, Samuel F.
Young, Charles A.

JUNIOR.

Jones, Marshall J. H.

The Secretary reported the death of one of the members of the Board of Direction, Mr. L. F. W. Hildner, who joined the Society April 1901 and

died June 1, 1923. After discussion, it was moved and carried that the Secretary write Mr. G. E. Klingelhofer and Samuel E. Duff asking them to prepare a memoir of Mr. Hildner.

The report of the Secretary, showing the financial condition of the Society at the close of business May 31st, having been audited by the Finance Committee, was approved.

Mr. R. Khuen, Chairman of the Civic Affairs Committee, reported that a meeting had been held to take up the matter of House Bill No. 611, an Act repealing the special act of 1873 which enacted to keep the County Engineer's office entirely from political influence, and stated that the bill had passed the Senate and had been called out of Committee by the House and, therefore, any action taken by the Society, would have to go direct to the Governor.

The Committee, therefore, recommends that the Board of Direction urge the Governor to veto this bill for the following reasons.

The continuity of the office of the County Engineer and his staff is very liable to be repeatedly interrupted, if it is thrown into politics, and it is believed that this would be detrimental to the best interests of the various counties of the State, as they will be deprived of the accumulated experience of the engineering staff.

The present method of selecting county engineers has proved entirely satisfactory, we believe, as it has a tendency to retain him in office as long as his services are satisfactory. All business corporations and firms pursue a similar policy, as it is proved the most efficient method from a business standpoint.

Your committee, therefore, recommends that the Board pass the necessary resolution to be forwarded to the Governor, as well as the various engineering Societies throughout the state, with the suggestion that the latter take similar action.

After discussion it was moved and carried that the report be approved and the Secretary and President authorized to draw up the proper communication to be sent to the Governor and the other Societies as suggested in the report.

In the absence of Mr. Hobbs, Chairman of the Entertainment Committee, the Secretary reported a very successful and pleasant trip to the National Works of the National Tube Co. in McKeesport, stating that there was an attendance of about 125. No further trips will be held this Spring but the Committee is planning to hold at least four or five in the Fall.

Mr. Leland, Chairman of the House Committee, reported an evening attendance of 163 for the month of May and further reported that the Bridge Contest was being held, the final night to be next Wednesday.

Mr. Spellmire, Chairman of the Membership Committee, reported that one meeting of the Committee had been held to assign the applications received since the last meeting of the Board of Direction and act upon any resignations received. It was recommended that the two resignations received should be accepted.

Mr. Knowles brought up the question of the publication of our year book, asking the expression of opinion from members of the Board as to whether or not we should include the Constitution and By Laws, which were omitted last year in order to cut down expenses.

After discussion it was moved and carried that the membership list be printed without the Constitution and By Laws.

It was suggested that the Entertainment Committee consider the possibility of a Golf Tournament for members of the Society sometime in the future.

The meeting adjourned at 5:15 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The 414th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, June 12th at 8:08 P. M., President Morris Knowles presiding, 45 members and visitors being present.

The Minutes of the last meeting held May 15th, were read and approved.

The Board of Direction reported the election of nine applicants to the grade of Member, five to the grade of Associate Member, one to the grade of Associate and one to the grade of Junior and the receipt of ten applications for membership. Three resignations were accepted and twenty-two members were dropped on account of non-payment of dues.

The prizes in the Annual Chess Tournament, presented by Mr. Wm. F. Hall and Mr. L. C. Frohrieb were awarded to the winners, Mr. E. D. Leland and Mr. A. Stucki, first and second respectively.

The winner of the Bridge Tournament will be announced at the September meeting.

No further business coming before the Society, the paper of the evening on "Modern Natural Gas Engineering" was presented by Mr. E. J. Stephany, Superintendent, Sales Dept., Equitable Gas Co., Pittsburgh, Pa.

Wrtten discussion was presented by W. C. Buell, Jr., Pres. Buell Scheib Mueller, Inc.; C. F. Freeman, Dist. Mgr., Surface Combustion Co.

The ensuing discussion was participated in by: A. E. Anderson, Attorney, Pittsburgh, Pa.; Morris Knowles, Pres. Morris Knowles Inc.; E. D. Leland, Gen. Mgr., Equitable Gas Co.; F. K. Howell, Supt., Compressing Stations, Philadelphia Co., E. O. Mueller, Secy., Buell, Scheib, Mueller, Inc.; Thomson King, Sales Mgr., Gas Boiler Dept., Peerless Heater Co.; J. I. Moyer, Geologist, Philadelphia Company; H. M. Henry, Branch Mgr., Combustion Utilities Corp.; A. E. Blake, Pittsburgh Repr., U. G. I. Contracting Co.; and the author.

The meeting adjourned at 10:45 P. M.

K. F. Treschow, *Secretary.*

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Ball Room, William Penn Hotel, Tuesday, June 5th at 8:25 P. M., Mr. W. C. Buell presiding in the absence of the Chairman, 172 members and visitors being present.

The Minutes of the last meeting held April 3rd were read and approved.

No further business coming before the Section, the paper of the evening on Pulverized Fuel for Boilers was presented by Messrs. J. C. Hobbs, Manager, Allegheny County Steam Heating Co. and L. W. Heller, General Superintendent, Power Stations, Duquesne Light Co., Pittsburgh, Pa.

Written discussion was presented by: W. C. Buell, Jr., Pres. Buell, Scheib Mueller, Inc.; J. B. Crane, V. P., George T. Ladd Co.; F. J. Crolius, Editor, Blast Furnace & Steel Plant.

The ensuing discussion was participated in by: Henry Kreisinger, Research Engr., Combustion Engineering Corp.; Joseph Breslove, Consulting Engineer, Pittsburgh, Pa.; A. E. Blake, Pgh. Repr., U. G. I. Contracting Co. of Philadelphia, Pittsburgh, Pa.; Edward Rahm, Jr., Mgr., Industrial Equipment Co.; and the author.

On motion the meeting adjourned at 10:50 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

SPECIAL MEETING

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Wednesday, July 11th at 5:00 P. M., President Morris Knowles presiding, Messrs. Hobbs, Dandridge, Leland, Ludgate, Spellmire, Ladd, Crabtree and the Secretary being present.

The President stated that he had called the meeting to acquaint the Board of Direction with what had transpired in connection with the renewed controversy in regard to the County Commissioners awarding the contract to architects for design and supervision of construction of bridges over the Allegheny River at 6th, 7th and 9th Streets.

The President stated that this subject had been brought up again in May when the question of complying with the order of the War Dept. in regard to our bridges was being discussed. At the suggestion of Mr. Lee, President of the Pittsburgh Chapter of the American Institute of Architects, a joint meeting of our Civic Affairs Committee and their Municipal Improvements Committee had been called to endeavor to submit a cooperative plan for the carrying on of this work to the County Commissioners. This Committee passed resolutions recommending that the County Engineer be put in charge of this work with such assistance on the architectural features and special engineering work as he might require.

However, it was learned a few days ago that the architects Municipal Improvements Committee had acted without the authority of its Chapter in submitting this suggestion and, therefore, the Board of Direction of the Pittsburgh Chapter of the American Institute of Architects was free to act as it desired.

In view of this action and of the recent propaganda in the newspapers. The President felt prompt action was necessary and had appeared before General Beach and the County Commissioners on Tuesday, stating that the Engineers still felt that this work should be carried on by the County Engineer, with an architect as a consultant on the architectural work. Furthermore, that this Society had, by resolution, indicated its approval of the action of its Committee in submitting the resolution which the architects had repudiated. Mr. Knowles explained that the authority for the Civic Affairs Committee to act in such a way is contained in the resolutions passed by the Society at its regular monthly meeting held Jan. 20, 1920.

The President then read to the Board the communication which he had presented to the Commissioners.

After a general discussion it was moved and carried that the action of the President and the Civic Affairs Committee be heartily endorsed by the Board of Direction and the thanks of the Board extended to the President for his prompt action on this very important matter.

The meeting adjourned at 5:30 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

SPECIAL MEETING

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, William Penn Hotel, Wednesday, Aug. 29th, at 1:45 P. M., President Morris Knowles presiding, Messrs. Crabtree, Spellmire, Leland, Eavenson, Ladd, Khuen, Ellis, Danforth, James and the Secretary being present.

The President stated that the meeting had been called to act upon the recommendation received from the Governing Council of the Associated Engineering Societies of Pittsburgh and approved by our Civic Affairs Committee, suggesting that the Engineers' Society send to its membership a brief notice calling attention to their responsibility as citizens and urging that they cast their vote at the coming election.

The President stated that the action of the Council had been prompted by criticism in the past to the effect that engineers had neglected to take interest in their local government. He also pointed out that this could not be considered as "playing politics" as we were not advocating any special person or persons, but merely pointing out the importance of their duty.

After a general discussion it was moved and carried that the Secretary be instructed to mail out the notice in accordance with the suggestion made by the Civic Affairs Committee.

The meeting adjourned at 2:15 P. M.

K. F. Treschow, *Secretary.*

CIVIL SECTION

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, Sept. 11th at 8:15 P. M., Chairman B. A. Ludgate presiding, 97 members and visitors being present.

The minutes of the last meeting held May 1st, were read and approved.

There being no further business coming before the Section, the paper of the evening on "Concrete Piles and Concrete Piling Construction" was presented by Mr. Maxwell M. Upson, V. P. & Gen. Mgr., Raymond Concrete Pile Co., New York, N. Y.

Written discussion was presented by: Edward Godfrey, Struct. Engr., Robt. W. Hunt & Co.; Frank G. Cunningham, Treas., Simplex Pile Foundation Co.

The ensuing discussion was participated in by: Julian Kennedy, Consulting Engineer, Pittsburgh; J. S. Martin, Struct. Engr., Philadelphia Company; N. F. Brown, Brown & Reppert, Inc.; J. A. Ferguson, Secy. Engr., Building Code Committee, City of Pittsburgh; S. C. Carter, Const. Engr., The Koppers Company; W. M. Austin, Elec. Engr., Westinghouse Elec. & Mfg. Co.; Harry J. Lewis, Consulting Engineer, Pittsburgh; B. A. Ludgate, Asst. Engr., P. & L. E. R. R. Co.; and the author.

On motion duly seconded and carried, a vote of thanks was extended to Mr. Upson for his very interesting and instructive paper.

The meeting adjourned at 10:03 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, September 25, at 4:30 P. M., President Morris Knowles presiding, Messrs. Ladd, Khuen, Leland, Danforth, Ludgate, Eavenson, Goodspeed and the Secretary being present.

The Minutes of the last meeting, held May 15, and of the special meetings held July 11 and August 29, were approved without reading.

Applications for membership from the following gentlemen, having been previously published to the Society in accordance with the action of the Board, were elected to membership:

MEMBERS

Ehmann, Roy Leon	McGonagle, Arthur
Fear, Thomas George	Schraishuhn, Theodore Adolphus

Stockdale, Henry S.

ASSOCIATE MEMBERS

Cox, Samuel F.	Ogden, Benjamin M.
Harkness, John C.	Wharton, William B.

ASSOCIATES

Briscoe, James	Young, Charles A.

JUNIOR

Jones, Marshall J. H.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Cramer, Robert Edward	Scott, Mahlon Douds
Hellan, Haakon	Shook, John Edward
King, Thomson	Stearns, Edw. W.
Porter, George, Jr.	Truebe, Paul G.
Quentin, George W.	Wood, R. U.

ASSOCIATE MEMBER

Findley, Harry Warren

ASSOCIATE

Cook, W. S.

The Secretary reported the death of Mr. P. N. Jones, who joined the Society May, 1902, and died July 2, 1923; also S. W. Black, who joined March, 1891, and died July 19, 1923.

The reports of the Secretary showing the financial condition of the Society at the close of business, June, July and August, having been audited by the Finance Committee, were approved.

Mr. Hobbs, Chairman of the Entertainment Committee, reported that arrangements were completed for the trip to Detroit on September 28, 29 and 30, and that indications pointed to a good attendance. Other trips are being arranged for the Fall, and the Committee has held one meeting to talk over tentative plans for the coming banquet.

Mr. Leland, Chairman of the House Committee, reported an evening attendance for the months of June, July and August of 526. He further reported that the attendance at our noonday luncheons had kept up exceptionally well this summer.

Mr. Spellmire, Chairman of the Membership Committee, reported that one meeting had been held to assign the applications received since the last meeting of the Board of Direction.

The meeting adjourned at 5:40 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

The 415th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, September 25, at 8:08 P. M., President Morris Knowles presiding, 87 members and visitors being present.

The Minutes of the last regular monthly meeting, held June 12, were read and approved.

The Board of Direction reported the election of four applicants to the grade of Member, two to the grade of Associate Member and four to the grade of Junior; the receipt of twelve applications for membership. There were also two resignations accepted and one death reported.

Mr. Knowles appointed the following gentlemen to serve on the Nominating Committee to nominate officers for the ensuing year: Richard Khuen, Jr., Chairman; Wm. F. Hall, N. F. Hopkins, A. L. Hoerr and R. M. Rush.

A motion picture on Centrifugal Steel Castings was shown by Mr. Harvey Allen, of the McConley-Torley Co.

No further business coming before the meeting, the paper of the evening was presented by Mr. A. E. Crockett, Mgr., Bureau of Instruction, Jones & Laughlin Steel Corp., Pittsburgh, on "River Transportation."

The ensuing discussion was participated in by: Howard L. Beach, Charles L. Clark & Howard L. Beach, Engineers, Pittsburgh; C. A. W. Brandt, Chf. Engr., Superheater Co., New York, N. Y.; George H. Danforth, Struct. Engr., Jones & Laughlin Steel Corp.; F. W. Hammil, Draftsman, S. S. Works, Jones & Laughlin Steel Corp.; Winters Haydock, Chf. Engr., Citizens' Committee on City Plan of Pittsburgh; Morris Knowles, Pres., Morris Knowles, Inc.; James S. Martin, Struct. Engr., Philadelphia Company; T. B. Sturges, Pres., Pennsylvania Drilling Co.; and the author.

On motion the meeting adjourned at 9:55 P. M.

K. F. TRESCHOW, *Secretary.*

STEEL WORKS SECTION

The regular bi-monthly meeting of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, September 18, at 8:20 P. M., Chairman G. M. Goodspeed presiding, 51 members and visitors being present.

The Minutes of the last meeting, held April 24, were read and approved.

There being no further business before the Section, the paper of the evening, on "Reactivity of Coke in Relation to Blast-Furnace Operation," was presented by Messrs. George St. J. Perrott, Assistant Physical Chemist, and Ralph S. Sherman, Assistant Physicist, U. S. Bureau of Mines, Pittsburgh, Pa.

The ensuing discussion was participated in by: George W. Hughes, Supt., Blast Furnaces, Pittsburgh Steel Co.; H. J. Rose, Chemist, The Koppers Company; Robert H. Schaller, Asst. Supt., Pittsburgh By-Products Coke Plant, Jones & Laughlin Steel Corp.; John S. Unger, Mgr., Research Bureau, Carnegie Steel Co.; G. W. Vreeland, Supt., Blast Furnaces, Carnegie Steel Co.; and the authors.

On motion, duly seconded and carried, a vote of thanks was extended to Messrs. Sherman and Perrott for their very interesting paper.

The meeting adjourned at 10:00 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, October 23rd at 4:40 P. M., Vice President Frederic Crabtree presiding in the absence of the President, Messrs. Hobbs, Khuen, Leland, James, Danforth, Eavenson, Goodspeed, Martin and the Secretary being present.

The Minutes of the last regular meeting held September 25th, were approved without reading.

Applications for membership from the following gentlemen, having been previously published to the Society in accordance with the action of the Board were elected to membership.

MEMBERS

Cramer, Robert Edward	Scott, Mahlon Douds
Hellan, Haakon	Shook, John Edward
King, Thomson	Stearns, Edw. W.
Porter, George, Jr.	Truebe, Paul G.
Quentin, George W.	Wood, R. U.

ASSOCIATE MEMBERS

Findley, Harry Warren

ASSOCIATE

Cook, W. S.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Botsai, Louis Roderick
Caldwell, Paul
Dethloff, William L.
Holiday, Harry
Fink, Samuel I.

ASSOCIATE MEMBERS

Sayer, Fred D.
Winder, Frank J.
Zeeryp, Henry Charles

ASSOCIATE

Hamill, Kennedy

The Secretary reported the death of Mr. George E. Tener, who joined the Society in May 1886 and died October 20, 1923.

The report of the Secretary showing the financial condition of the Society at the close of business September 30th, having been audited by the Finance Committee, was approved.

Mr. Hobbs, Chairman of the Entertainment Committee reported a most successful trip to Detroit, with a total attendance of 85. He reported that due to the aid we received through a subscription dinner held Saturday evening in Detroit we were able to hold down the expenses of the trip to $69.40. It is the intention of the Committee to try another trip along these lines early next Spring and one or two places have already been suggested.

The Committee is now working on the Annual Banquet and hopes to have a definite announcement by the November meeting of the Board.

In the absence of Mr. Ladd, Chairman of the Finance Committee, the Secretary reported that a contribution of $500.00 was received from Mr. H. B. Rust of the Koppers Co. We also have tentative promises from two or three other firms which should be received before the next meeting of the Board.

Mr. Leland, Chairman of the House Committee, reported an evening attendance of 187 for the month of September. He also reported that we had secured a lease from Mr. Butler covering our present quarters at the same rate we have been paying, for one year. Mr. Leland asked the authority of the Board for the President and Secretary to execute this lease. It was moved and carried that the President and Secretary be authorized to sign the lease.

In the absence of Mr. Spellmire, Chairman of the Membership Committee, the Secretary reported that one meeting had been held to assign the application received since the last meeting of the Board of Direction and act upon any resignations.

MEDAL AWARDS

The Secretary presented the following report of the Medal Awards Committee for the year 1922 and after discussion, it was moved and carried that the Silver Medal be awarded to Mr. James S. Martin.

September 26, 1923.

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

A meeting of the Medal Awards Committee was held in the Society Room, William Penn Hotel Sept. 26th, at 4:30 P. M. at which it was decided to award the silver medal to James S. Martin for his paper on "Structural Engineering Problems in Transmission-Line Construction."

Respectfully submitted,

F. I. Ellis, *Chairman*
G. H. Danforth
H. D. James
Medal Awards Committee.

The Secretary was instructed to secure the silver medal for presentation to Mr. Martin.

The Secretary read the following letter from Mr. W. C. Buell:

Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

A considerable amount of valuable work has been finished or is in progress by a number of the larger engineering societies, notably The American Society of Mechanical Engineers, The American Society for Testing Materials, the American Engineering Standards Committee and others specifying standard test methods for fuel using equipment such as steam boilers, and gas producers, and these so-called codes form the basis of all approved performance tests on apparatus of those classes.

While the codes specify the method of procedure, they do not cover in detail nor specify the chemical and physical data to be used or the method of calculating such data as is to be incorporated into the test figures.

There is a multitude of thermo-chemical and thermo-physical data in the various hand books, and other published sources of information of this kind, and often figures given for the same subject are greatly at variance. Also much data of this sort that is found in the hand books is, in the light of more recent research obsolete.

The use of data from various sources will often show difference so great as to materially modify final figures if test data is calculated from figures of different authorities and it is believed that it would be of great value to the engineering profession as a whole to have established as standards on thermo-physical and thermo-chemical data such as may be used in the tests of combustion equipment.

Now we, the undersigned, do herewith recommend to you that a committee be appointed to consider this subject, and if found advisable and desirable to proceed, to recommend that this work be carried on or otherwise.

We further recommend, that this committee be called the Combustion Standards Committee, that the preliminary investigation be conducted by five members of the Society to be named by you. If reported desirable to go ahead with this work, the committee be enlarged to ten members of our Society, and that such of the National Societies as may be interested be invited to name an individual to act on this committee.

It is further suggested that the original committee be empowered and directed to approach the National Societies by correspondence, or otherwise, on the general subject and to secure their views as to the desirability of our Society in undertaking this work, and if possible their active cooperation.

It is our opinion that a work of this nature if successfully consummated would be of great value to the engineering profession, and would be the means of bringing the name of our Society prominently and favorably before a large number of engineers.

Respectfully submitted,

(Signed) W. C. Buell, Jr.

It was moved and carried that the President be authorized to appoint a committee of five to investigate the possibilities of this recommendation and report back to the Board at its next meeting.

The meeting adjourned at 5:30 P. M.

K. F. Treschow,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, Oct. 9th, at 8:20 P. M., Chairman E. P. Dandridge presiding, 40 members and visitors being present.

The Minutes of the last regular meeting held June 5th, were read and approved.

No further business coming before the Section, the paper of the evening on "The Relations Between the Engineering and Operating Departments was presented by Mr. F. J. Crolius, Editor, Blast Furnace and Steel Plant, Pittsburgh, Pa.

The ensuing discussion was participated in by: E. Willis Whited, Instructor, Industrial Engineerng, University of Pittsburgh; J. H. Simpson, South Side Works, Jones & Laughlin Steel Corp; V. B. Edwards, Gen. Mgr., Engineering Works Dept., Dravo Contracting Co.; E. P. Dandridge, Dist. Mgr., Stephens-Adamson Mfg Co., and the author.

There being no further discussion, the meeting adjourned at 9:25 P. M.

K. F. Treschow,
Secretary.

REGULAR MONTHLY MEETING

The 416th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, October 23rd, at 8:11 P. M., Vice President Frederic Crabtree presiding, in the absence of the President, 60 members and visitors being present.

The Minutes of the last meeting held September 25th were read and approved.

The Board of Direction reported the election of five applicants to the grade of Member, four to the grade of Associate Member, two to the grade of Associate and one to the grade of Junior, and the receipt of twelve applications for membership. Four resignations were accepted and two deaths reported.

No further business coming before the Society, a lecture on "Hunting the Great Dinosaurs" was given by Mr. Arthur Coggeshall, Paleontologist and Curator of Education, Carnegie Museum, Pittsburgh, Pa.

A very interesting discussion of the subject followed the lecture.

On motion duly seconded and passed, a vote of thanks was extended to Mr. Coggeshall for his very interesting and enjoyable talk.

The meeting adjourned at 10:25 P. M.

K. F. Treschow,
Secretary.

MINING SECTION

The regular bi-monthly meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, October 30th at 8:05 P. M., Chairman H. N. Eavenson presiding, 67 members and visitors being present.

The Minutes of the last meeting held May 29th were read and approved.

No further business coming before the Section, the paper of the evening on "Thick Freeport Coal" was presented by Mr. John M. Rayburn, Civil & Mining Engineer, Pittsburgh, Pa.

The ensuing discussion was participated in by: R. Thiesen, Associate Research Chemist, U. S. Bureau of Mines; W. E. Fohl, Consulting Mining Engineer, Pittsburgh; Thos. G. Fear, Supt., Inland Collieries Co., Indianola, Pa.; F. K. Howell, Supt., Compressing Stations, Equitable Gas Co.; W. A. Weldin, Blum, Weldin & Co; Max Hecht, Chemist, Duquesne Light Co.; Howard N. Eavenson, Howard N. Eavenson & Associates; J. H. Gerst, Engineer, John M. Rayburn, Civil & Mining Engineer; and the author.

On motion duly seconded and carried, a vote of thanks was extended to Mr. Rayburn for his very excellent and interesting paper.

The meeting adjourned at 10:10 P. M.

K. F. TRESCHOW,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, November 20th at 4:40 P. M., President Morris Knowles presiding, Messrs. Spellmire, Ladd, Hobbs, Leland, Goodspeed, Danforth and the Secretary being present.

The Minutes of the last regular meeting held October 23rd, were approved without reading.

Applications for membership from the following gentlemen, having been published to the Society in accordance with the action of the Board, were elected to membership.

MEMBERS

Botsai, Louis Roderick
Caldwell, Paul
Fink, Samuel I.
Dethloff William L.
Holiday Harry

ASSOCIATE MEMBERS

Sayer, Fred D.
Winder, Frank J.
Zeeryp, Henry Charles

ASSOCIATES

Hamill, Kennedy

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Backman, Lester John
Bay, Frederick Raymond
Bright, Graham
Davis, Clyde Ellsworth
Keller, Joseph Jerome Blake
Leathers, Harry M.
Rodgers, Wesley R.
Tylee, Don O.

ASSOCIATE MEMBERS

Leeper, J. B.
Ellman, Louis
Cundy, Oscar R.

JUNIOR

VanHook E. B.

Letters of resignation were received from the following gentlemen and after a discussion, they were ordered accepted: Lambie, A. L.; Lyon, James F.; Maxfield, H. H.

The report of the Secretary showing the financial condition of the Society at the close of business October 31st, having been audited by the Finance Committee, was approved.

In accordance with Article 5, Section 5 of the By-Laws, the following report of the Nominating Committee was presented.

November 13, 1923.

To the Board of Direction,

Engineers' Society of Western Pennsylvania.

Dear Sirs:

Your Nominating Committee appointed to nominate officers for the ensuing year, held a meeting Monday, November 12th and beg to report the following:

For President .... Frederic Crabtree
For Vice President.................... W. E. Fohl
For Treasurer .... A. Stucki
For Directors .... G. M. Goodspeed, W. A. Weldin

Respectfully submitted,

Richard Khuen, Jr., *Chairman*
Wm. F. Hall
N. F. Hopkins
A. L. Hoerr
R. M. Rush

Nominating Committee.

It was moved and carried that the report of the Committee be approved and the Secretary instructed to publish the names in accordance with the By-Laws.

Mr. Hobbs, Chairman of the Entertainment Committee, reported that arrangements had been completed for an inspection trip to the American Zinc & Chemical Co. plant at Langeloth on Saturday, December 1st and that arrangements for the Annual Dinner were well under way.

The Secretary reported on behalf of the Finance Committee that contributions to the special fund now total $4500 and that word had been received from three companies, each promising $500, which will bring the total to $6000. If this $1500 is secured, we will only need $1500 more to wipe out the deficit of $8900 which we had the first of the year.

The advertising is still coming in and it is hoped that we may be able to secure enough to bring the total to $5000 before the end of the year. With the advertising now on the books, the October and November issues have been paid for by the advertising, both cuts and printing.

The Committee also reports having sent out bills and letters to members delinquent in dues and it is planned to send out another bill shortly after the first of December to those who have not paid up.

Mr. Leland, Chairman of the House Committee, reported an evening attendance in the Society rooms for the month of November of 223.

Mr. Spellmire, Chairman of the Membership Committee, reported that one meeting of the Committee had been held to assign the applications received since the last meeting of the Board and act upon any resignations.

The President brought up the matter of recent action by the Board of Direction of the American Society of Civil Engineers in protesting against the dismissal of Arthur P. Davis of the Reclamation Service by Secretary Work of the Department of the Interior. Mr. Knowles asked the Secretary to read copy of the letter sent to Secretary Work by the Board of Direction of the A. S. C. E. After a general discussion, it was moved and carried that this matter be referred to the Civic Affairs Committee with the request that they report back to the Board at its next meeting.

The Secretary read a letter from the National Industrial Conference Board, asking us to appoint delegates to attend the National Immigration Conference to be held December 13th and 14th in New York City It was moved and carried that the Secretary communicate with one of the members in New York, asking him to represent the Society at this meeting.

The President brought up the matter of the Engineers' Society having a representative membership in the Chamber of Commerce and recommended that the membership be taken out in the name of the Society. After discussion it was moved and carried that this matter be referred to the Civic Affairs Committee for their recommendation.

The Secretary presented a letter from the Executive Secretary of the Federated American Engineering Societies stating that the Executive Board of the American Engineering Council had instructed him to extend an invitation to our Society to send one or more delegates to the American Engineering Council meeting to be held in Washington January 9 to 11, also to attend the Conference on Public Works to be held January 9th. It was moved and carried that the Secretary write Mr. E. F. Wendt, asking him to serve as our representative at this meeting.

The meeting adjourned at 5:45 P. M.

K. F. TRESCHOW,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, December 11th, at 4:40 P. M., President Morris Knowles presiding, Messrs. Crabtree, Stucki, Ludgate, Eavenson, Goodspeed, Ladd, and the Secretary being present.

The Minutes of the last regular meeting held November 20th were approved without reading.

Applications for membership from the following gentlemen, having been published to the Society in accordance with the action of the Board, were elected to membership.

MEMBERS

Backman, Lester John
Bay, Frederick Raymond
Bright, Graham
Davis, Clyde Ellsworth
Keller Joseph Jerome Blake
Leathers, Harry M.
Rodgers, Wesley P.
Tylee, Don O.

ASSOCIATE MEMBERS

Leeper, J. B.
Ellman, Louis
Cundy, Oscar R.

JUNIOR

Van Hook, E. B.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Hiller, August — Mechesney, Charles Alexander
Houssman John — Millard, Emmor Hamilton
Walker, James Blair

ASSOCIATE MEMBERS

Crowder, R. — McMahon, James Joseph

JUNIOR

Witney, William Leslie

Requests were made by the following that they be transferred to a higher grade of membership and after discussion, the Secretary was requested to advise them that they were transferred to the grade of Member.

Fred D. Sayer — E. C. Dilworth

Letters of resignation were received from the following gentlemen and after discussion, they were ordered accepted.

B. F. Groat — G. E. Warren
R. A. Harbaugh — A. R. Tegge

The report of the Secretary showing the financial condition of the Society at the close of business November 30th, having been audited by the Finance Committee, was aproved.

Mr. Khuen, Chairman of the Civic Affairs Committee, stated that a meeting had been held to take up the matter referred to the Board of Direction at its last meeting in regard to the removal of Director Arthur P. Davis of the Reclamation Service by Secretary Work. Mr. Khuen stated that various national Societies and local societies throughout the country had passed resolutions protesting against the removal of Director Davis and that the Federated American Engineering Societies had requested all organizations to take similar action.

Particular attention was called to the resolution passed by the directors of the American Society of Civil Engineers and to an article which appeared in the November 22nd issue of the Engineering News-Record.

After a general discussion, during which it was pointed out that passing a resolution at this late date would merely be a duplication of what others had already done, it was moved and carried that the Committee recommend that the following letter be sent to Secretary Work and the two senators with such additional information or correction as the Board may deem advisable.

Hon. Hubert Work,

Secretary of the Interior, Washington, D. C.

Sir:

This Society has been and is in thorough accord with the resolutions which have been sent to you by various national engineering societies with respect to the removal of Arthur P. Davis, as Director of the Reclamation Service.

While a protest to you would seem to be merely a duplication of the action of these organization, in view of the current press reports which indicate mismanagement of this department due to improper political influence

the Engineers' Society of Western Pennsylvania hereby desires to place itself on record as fully endorsing the resolutions already filed by the American Society of Civil Engineers and other engineering organizations.

Yours very truly,

After a general discussion, it was moved and carried that the recommendation of the Committee with reference to letter being written to Hon. Hubert Work be approved with the corrections as shown above, also that the matter be referred to the General Society at their meeting to be held this evening for their action.

Mr. Khuen stated that the matter of the Society taking out a membership in the Chamber of Commerce in the name of the Society was also taken up at this meeting and the recommendation made that this be done.

After a general discussion it was moved and carried that the recommendation of the Committee be approved.

Mr. Fleming, a member of the Civic Affairs Committee brought up the matter of the Society taking action in endorsing the present county engineer for reappointment in view of the law recently passed which places this position under the control of the County Commissioners. Mr. Fleming stated that some of the members had asked him to take the matter up with the Society asking that they endorse Mr. Covell for reappointment. It was recommended to the Board of Direction that the Society endorse Mr. Covell for reappointment.

It was moved and carried that the Secretary and President be authorized to send a letter to the County Commissioners pointing out the advantages of continuity of service in office of the County Engineer.

In the absence of Mr. Hobbs, Chairman of the Entertainment Committee, the Secretary reported that arrangements had been completed for an informal party to be held in the William Penn Hotel, Monday evening, December 17th and stated that the House Committee was especially anxious to secure a good turnout and urged the Board to make an effort to be present and also to call it to the attention of as many members as possible.

Arrangements are being completed for the Annual Banquet and it is hoped to have out the advance announcement within the next few weeks.

Mr. Ladd, Chairman of the Finance Committee, reported that two additional advertisements at $200.00 each, one with the Rush Machinery Co. and the other Carpenter & Byrnes.

In the absence of Mr. Leland, Chairman of the House Committee, the Secretary reported an evening attendance of 297 for the month of November.

In the absence of Mr. Spellmire, Chairman of the Membership Committee, the Secretary reported that the meeting of the committee had been held to assign the applications received since the last meeting of the Board of Direction.

In accordance with Article 5, Section 5 of the By-Laws, it was moved and carried that the nominations as published to the Society be finally approved and that letter ballots be mailed to the entire membership in accordance with the By-Laws.

The Secretary presented a letter from Mr. James O. Handy asking the endorsement of this Society of the plan to establish a downtown branch of the Carnegie Library of Pittsburgh. Mr. Handy stated that this matter had been brought to the attention of the Mayor who was in favor of it and to the Budget Committee of Council, who are believed to be in favor of it.

It was moved and carried that the Board of Direction endorse this recommendation and that the Secretary be instructed to write the proper authorities accordingly.

The matter of the inadequacy of our present quarters was brought up for discussion and it was pointed out that quite a number of the members had been suggesting that the Society take the room adjoining our present room, known as the Hawaiian Room as we are overcrowded every day during the noon hour.

After a general discussion, it was moved and carried that this matter be referred to the House Committee with the request that they endeavor to formulate a plan for presentation to the Board of Direction at its next meeting.

The meeting adjourned at 5:45 P. M.

K. F. Treschow,
Secretary.

JOINT MEETING

CIVIL SECTION

ENGINEERS' SOCIETY OF WESTERN PENNA.
and
PITTSBURGH SECTION, AMERICAN SOCIETY OF CIVIL ENGINEERS

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in conjunction with the Pittsburgh Section of the American Society of Civil Engineers, in the Blue Room, William Penn Hotel, Tuesday, November 13th at 8:10 P. M., Chairman B. A. Ludgate presiding, 84 members and visitors being present.

Mr. Schein, Secretary of the A. S. C. E., made several announcements to members of his Section.

No further business coming before the Section, the paper of the evening on "The Erection of the Southern Railroad Bridge Over the Ohio River at Cincinnnati" was presented by Mr. Frederic W. Henrici, Assistant Engineer, Erecting Department, American Bridge Co., Pittsburgh, Pa.

The ensuing discussion was participated in by: J. P. Leaf, City and Consulting Engineer, Rochester, Pa.; E. C. Dilworth, Cons. Engr., Pittsburgh; C. S. Davis, Cons. Engr., Pittsburgh; Richard Hirsch, Mech. Engr., H. K. Porter Company; Paul W. Whitman, Riter Conley Co.; W. M. Austin, Elec. Engr., Westinghouse Elec. & Mfg. Co.; A. A. Culler, Struct. Engr., Rutan Russell & Wood; B. A. Ludgate, Asst. Engr., P. & L. E. R. R. Company; and the author.

On motion of Mr. Braden, duly seconded and carried, it was voted to extend thanks to Mr. Henrici for his very interesting paper.

The meeting adjourned at 10:10 P. M.

K. F. Treschow,
Secretary.

REGULAR MONTHLY MEETING

The 417th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Chapter of the Illuminating Engineering Society in the Hawaiian Room, William Penn Hotel, Tuesday, November 20th at 8:20 P. M., President Morris Knowles presiding, 66 members and visitors being present.

The Minutes of the last regular meeting held October 23rd were read and approved.

The Board of Direction reported the election of ten applicants to the grade of Member, one to the grade of Associate Member, and one to the gråde of Associate and the receipt of nine applications for membership; one resignation accepted and one death reported.

The President announced that the silver medal had been awarded to Mr. James S. Martin for his paper on "Structural Engineering Problems in Transmission Line Construction" and the medal was presented to Mr. Martin.

No further business coming before the Society, the paper of the evening on "The Control of Light for Industrial Use" was presented by J. M. Ketch, Illuminating Engineer, National Lamp Works, Cleveland, Ohio.

There was a general discussion of the paper after its presentation.

On motion duly seconded and carried a vote of thanks was extended to Mr. Ketch for his very interesting paper.

The meeting adjourned at 10:20 P. M.

K. F. Treschow,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, December 4th at 8:20 P. M., Mr. W. C. Buell, acting as chairman in the absence of the Chairman and Vice Chairman, 67 members and visitors being present.

The Minutes of the last meeting held October 9th, were read and approved.

No further business coming before the Section, the paper of the evening on "Modern Methods of Bolt and Nut Manufacture" was presented by Mr. W. B. Peirce, Works Manager, Graham Bolt & Nut Co., Coraopolis, Pa.

The ensuing discussion was participated in by: Mr. Lamb, Sales Manager, Waterbury-Farrel Fdry Co., Cleveland, Ohio; H. T. Eaton, Mech. Draftsman, Oliver Iron & Steel Corp.; A. Stucki, Cons. Engr., Pittsburgh; William Buhl, Sales Engr., Dravo-Doyle Co.; Max Hecht, Chemist, Duquesne Light Co.; J. J. Shuman, Inspecting Engr., Jones & Laughlin Steel Corp.; W. V. Dermitt, Agent & Mfgrs. Repr., Sanymetal Products Co., Pittsburgh; and the author.

On motion duly seconded and carried, a vote of thanks was extended to Mr. Peirce for his very interesting paper.

The meeting adjourned at 9:53 P. M.

K. F. Treschow,
Secretary.

MINING SECTION

The regular bi-monthly meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, December 18th at 8:15 P. M., Chairman H. N. Eavenson presiding, 47 members and visitors being present.

The Minutes of the last meeting, held October 30th, were read and approved.

There being no further business, the paper of the evening on "A New Belgian Process of Washing Coal—The Rheolaveur" was presented by Messrs. Y. Kersten and A. Andry, Belgian Mining Engineers of Brussels and Liege, Belgium.

The ensuing discussion was participated in by: E. G. Hill, Professor, School of Mines, University of Pittsburgh; R. W. Arms, Roberts & Schaefer Co., Chicago, Ill.; and the authors.

On motion duly seconded and carried, a vote of thanks was extended to Messrs. Kertsen & Andry for their very interesting paper.

The meeting adjourned at 10:00 P. M.

K. F. Treschow,
Secretary.

REGULAR MONTHLY MEETING

The 418th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Hawaiian Room, William Penn Hotel, Tuesday, December 11th at 8:00 P. M., President Morris Knowles presiding, 45 members and visitors being present.

The Minutes of the last regular meeting held November 20th, were read and approved.

The Board of Direction reported the election of five applicants to the grade of Member, three to the grade of Associate Member, and one to the grade of Associate; also the receipt of twelve applications for membership and three resignations were accepted.

A resolution was presented by the Civic Affairs Committee, which was approved by the Board of Direction, protesting against the removal of Arthur P. Davis, from the Reclamation Service and on motion duly seconded and passed unanimously, the resolution was adopted and the Secretary instructed to send copies to the Secretary of the Interior, to the President and to the two Senators from Pennsylvania.

There being no further business coming before the Society, Dr. Heber D. Curtis, Director of Allegheny Observatory, Pittsburgh, Pa., gave a lecture on "Eclipse Experiences in Mexico.

A general discussion followed the lecture.

On motion duly seconded and carried, a vote of thanks was extended to Dr. Curtis for his very interesting lecture.

The meeting adjourned at 10:20 P. M.

K. F. Treschow,
Secretary.

Vol. 39 FEBRUARY 1923 No. 1

PROCEEDINGS

OF THE

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

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ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

Incorporated 1880

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CURRENT PERIODICALS

IN THE READING ROOM OF THE SOCIETY

Academy of Natural Sciences of Philadelphia. Proceedings.

American Institute of Architects. Journal.

American Institute of Electrical Engineers. Journal

American Machinist

American Roofer

American Society of Civil Engineers. Proceedings

American Society of Mechanical Engineers. Journal

American Society of Naval Engineers. Journal

Arkitektur

Association of Chinese and American Engineers. Journal

Association of Iron and Steel Electrical Engineers. Journal

Blast Furnace and Steel Plant

Boston Society of Civil Engineers. Journal

Builders' Bulletin, The

Bulletin, The

Chamber of Mines, Monthly Journal

Chemical Age, The

Chemical Industry

Chemical and Metallurgical Engineering

Chemical News

Coal Age

Coal Industry

Coal Trade Bulletin

Colliery Guardian

Compressed Air Magazine

Concrete

Cornell Civil Engineer

Electric Journal

Electric Railway Journal

Electrical Review

Electrical World

Eliktrische Kraftbetriebe u. Bahnen

Engineering

Engineering Institute of Canada. Journal

Engineering News-Record

Engineering Production

Engineering and Contracting

Engineering and Mining Journal

Engineering Review

Engineers' Club of Philadelphia. Journal

Engineers' Club of St. Louis. Journal

Feuerungstechnik

Finance and Industry

Forging and Heat Treating

Franklin Institute. Journal

Gluckauf

Great Britain—Patent Office. Illustrated Official Journal

Heating and Ventilating Magazine

Industrial Management

Institution of Mechanical Engineers. Journal

Institution of Mining Engineers. Transactions

Iowa Engineering Society. Proceedings

Iron Age

Iron and Coal Trades Review

Iron Trade Review

Journal of Industrial and Engineering Chemistry.

Journal of the United States Artillery
Keramische Rundschau
L'Association des Ingenieurs. Annales
Liverpool Engineering Society Transactions
Mechanical Engineering
Military Engineer, The
Mining Congress. Journal
Mining and Metallurgy.
National Engineer
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New England Water Works Association. Journal
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Pittsburgh First
Popular Engineer
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Power
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Professional Engineer
Public Works
Railway Age
Railway Club of Pittsburgh Proceedings
Revue de L'Enginieur
Royal Society of Arts. Journal
Safety Engineering
Sanitary and Heating Engineering
Scientific American
Sheet Metal Worker
Siemens Zeitschrift
Sociedad Cientifica Argentina. Anales
Society of Automotive Engineers. Journal
Society of Chemical Industry. Journal
Stahl und Eisen
Stevens Indicator
St. Louis Railway Club. Official Proceedings.
Stone and Webster Journal
Successful Methods
Technical Review, The
Teknisk Tidskrift
United States—Patent Office. Official Gazette
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THE PENN COUPLER

This coupler, which is a combination and modification of the Pitt and Janney X Couplers manufactured by us, has all the desirable features of those couplers, and at the same time retains the simplicity of the early types of the Janney Coupler.

This coupler has the features of a "Lock-Set," a "Lock-to-the-Lock" and a "Knuckle-Opener," and complies fully with all the requirements and recommendations of the M. C. B. Association and the Safety Appliance Law.

Lock-Set. Lock setting is accomplished by the locking block when raised to the uncoupling position, resting on a seat on the inside wall of the coupler head, from which seat it is dislodged by the movement of the knuckle.

Lock-to-the-Lock. The locking pin cannot climb, being held in the locked position by the trigger, a projection near the upper end of which engages the under side of the top wall of the coupler head, thus preventing accidental uncoupling.

Knuckle-Opener. The knuckle-opener pushes the knuckle open to its fullest range of movement from a fully closed position or from any partially open position, and its path of movement is such as to insure easy and complete opening of the knuckle.

Especial attention is called to the large area (practically 5 square inches) of the locking surface on the locking block and the knuckle in this coupler, and to the fact that no portion of the locking block extends beyond the bottom wall of the coupler.

This coupler has the desirable feature of easy accessibility of parts, thus facilitating repairs.

Manufactured by

The McCONWAY & TORLEY CO.

PITTSBURGH, PA.

MALLEABLE IRON AND STEEL CASTINGS

Vol. 39 FEBRUARY 1923 No. 1

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OF THE

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Mining Coal by the Stripping Method - - - *S. A. Taylor*

The Modern Industrial Gear - *W. H. Phillips and L. F. Burnham*

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